disaster epidemiology

descriptive and analytic methods

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Outline

1. introduction to disaster epidemiology
   - definitions
   - three recent and two earlier disasters
   - case study: the titanic
2. epidemiology and disaster preparedness
   - preparedness, response and recovery
   - recovery and surveillance
3. case study: repatriation following hurricane katrina
   - Bayes, BUGS and R
   - orleans parish before and after hurricane katrina
4. conclusions

back to the future

rev. thomas bayes (1702-1761)

"a Bayesian is one who, vaguely expecting a horse, and catching a glimpse of a donkey, strongly believes he has seen a mule"

back to the future

dr. john snow (1813-1858)

"nature makes the experiments, and we watch and understand them if we can" (AB Hill)

Outline

what is epidemiology?

the study of the distribution and determinants of disease in (human) populations

- basic science of public health - methods, study designs, statistical approaches
- descriptive - agent, host environments
- analytic - associations (causality?)
- statistics and chance


AL-1
DMAT
AID STATION
NATIONAL DISASTER MEDICAL SYSTEM
U.S. PUBLIC HEALTH SERVICE, PHS-DMAT


AL-1
DMAT


AL-1
DMAT

what is a disaster?

quantitative
- more than 100 deaths or \$1 million damage (Sheehan and Hewitt, 1969)
- the bradford disaster scale
  - global annihilation = magnitude 10
  - 25K deaths = magnitude 4.3

legal "any natural catastrophe ...regardless of cause...which, in the determination of the President causes damage of sufficient severity and magnitude..."

perception "ordinary people will tell us what disasters are if we listen to them" (Kroll-Smith and Gunter, in Qurantelli, 1998)

an epidemiological definition of disasters

person the occurrance of more death, injury, disease, or psychiatric illness in a community than would be expected

time sudden, brief and intense causal mechanism

- natural vs. man-made
- "slow-moving disasters"

place

- circumscribed by geography or political boundaries
- ⋆ population and environmental vulnerabilities ⋆ "conditions prevalent in the...community (are) a better determinant of epidemiological impact than the physical characteristics of the event." (Sapir and Lechat)

Outline

three recent disasters

assessing the impact of 3 recent disasters

two earlier disasters

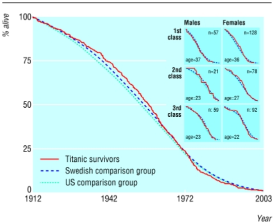
parameter	'72 Managua	'71 California
richter scale	5.6	6.6
geographic extent	$100 km^2$	$1500 km^2$
population exposed	420K	7 million
dead	5,000	60
injured	20,000	2,540

Outline

their hearts will go on

case fatality rate

class	men	women	children	total
1	.67	.3	0	.38
2	.92	.14	0	.59
3	.84	.54	.66	.62
total	.82	.26	.48	.62



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disaster planning phases

preparedness	interdisaster training, building, warning
response	emergency impact, extrication, treatment, food, shelter
recovery	post-impact rehabilitation, reconstruction

a haddon matrix for disasters

Noji and Sivertson

	PRE-DISASTER	DISASTER	POST-DISASTER
AGENT	identify potential terrorists		farming practices
HOST	discourage migration to disaster-prone urban areas	evacuation, shelter, (safe) food drops	prevent volunteer over-convergence
ENVIRONMENT	warning systems	levees	forensic engineering analyses

preparedness

vulnerability assessment

- map risks
  - previous events by location and frequency and impact
  - population density and characteristics
  - environmental hazards and vulnerable structures
- inventory resources
  - infrastructure
  - equipment
  - personnel
  - transportation
  - $\star$ *communication*
- training
  - pod drills, table tops
  - sns, surge capacity
  - education, outreach

response

emergency aid

- most deaths occur during the first hour
- most life-saving aid is provided by families, friends and neighbors
- external aid is often too late, and frequently inappropriate

'external disaster relief should focus on reducing population vulnerability and invest in structural changes to health care' (Sapir and Lechat)

response

health objectives

- prevent death
- treat injured and ill
- provide housing
- prevent illness due to communicable disease, lack of health care and malnutrition
- address acute psychiatric pathology and psychological distress

'generalized panic, paralyzing trauma or anti-social behavior rarely occur after major disasters' (Lazzari)

response

observation and surveys

- data to make informed decisions
  - '...the sacrifice in promptness required to collect the information necessary to provide apt and well-directed aid is more than justified by the improved results'
- damaged infrastructure, no uniform definitions, multiple conflicting sources
  - 'injury surveillance questionaires ... prepared before a disaster (that) can be modified quickly' (Noji)

Outline

recovery
surveillance

the ongoing systematic collection, analysis, interpretation and dissemination of health data

traditional in place prior to disaster, active vs. passive

non-traditional drop-in, syndromic (ED, pharmacy fills), relief workers, newspaper accounts, *spatial*

air and ground surveys

air and ground surveys

air and ground surveys

air and ground surveys

nyt

spatial analysis and mapping

person
: good methods to *analyze* nested, correlated data, e.g glm, mixed models

place
: good methods available to *identify* geographic clustering, e.g. SatScan, Moran's I

person-place
: Bayesian hierarchical models allow both identification and analysis

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the problem(s) of spatial data

- *any* data anlaysis following a disaster is difficult
- spatial data has unique statistical issues
  - counts
  - irregularly arrayed (aereal vs. lattice)
  - population and geographic characteristics correlated in time and space
  - overdispersed (Poisson)

measuring risk spatially

- SMR
  - y_i - observed count region i
  - e_i - expected count region i
  - θ_i - relative risk region i (unknown parameter)
- $smr = \frac{y_i}{e_i}$ - crude estimate for θ_i
- *but ... smr notoriously unstable and potentialy misleading*
  - non-independent observations, overdispersed, sensitive to denominator e_i
  - WHO discourages use of smr's in maps

smoothing risk estimates

- number of approaches available
- Bayesian approach
  - demonstrated to be effective and stable
- establish the probability of a risk estimate (*the posterior distribution*) given the data we collected (*the likelihood*) and what we expected to see (*the prior distribution*)
  - $Pr[\theta|y] \propto Pr[\theta]Pr[y|\theta]$
- when in doubt, repeat: *the posterior equals the prior times the likelihood*

Gamma prior distribution

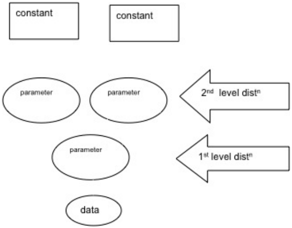
- the prior expectation of risk (θ) in spatial setting commonly defined as gamma ($\theta \sim \Gamma(a, b)$)
- $\mu = \frac{a}{b}, var = \frac{a}{b^2}$
- flexible
  - $\Gamma(1, b) \sim$ exponential
  - $\Gamma(\frac{1}{2}, (\frac{1}{2}) \sim \chi^2$
- constrained to be positive
- null model: $\Gamma(a = b) \sim 1$

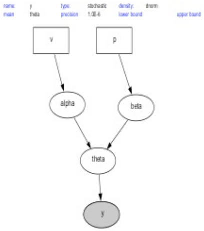
Poisson likelihood

- the distribution of rare events
- counts
- single parameter
  - $Pois(\lambda) = e^{-\lambda^k/k!}, \mu = \lambda, var = \lambda$
  - $Pr[k] = \frac{\lambda^k}{k!} e^{-\lambda}$
- observed spatial data: $y_i iid \sim Pois(\lambda_i = e_i \cdot \theta_i)$
- i.e. $E(y_i) = \lambda_i =$ expected count x risk
- *conjugate* to Gamma (same family)

hyperparameters

- Bayesian approach puts distribution on parameters
- so each parameter has its own paramters
- $y_i \sim Pois(e_i\theta_i)$
- $\theta_i \sim \Gamma(\alpha, \beta)$
- $\alpha \sim exp(\nu)$, $\beta \sim exp(\rho)$





model statement

```
model{
  for (i in 1:m){
       y[i]~dpois(lambda[i])       # Poisson likelihood (data)
       lambda[i]<-e[i]*theta[i]
       theta[i]~dgamma(a,b)        # prior for relative risk
                }
       a~dexp(0.1)                 # hyperpriors
       b~dexp(0.1)
      {
```

the log-linear transformation

- log link: $ln(\lambda) = C1 + C2$
- where
  - $C1 = \beta x_i$ log-linear transformation
  - C2 = other terms (e.g. predictors, random effect, spatial effect)
- create analytic models from gamma-poisson

the random effects term

- theoretically useful way to account for unstructured heterogeneity in data (spatial or otherwise)
  - variance ('noise') $>$ accounted by model
  - ?unmeasured confounding
- practically
  - partition the error or residual term ($\hat{\epsilon} \sim nl(0, \sigma^2)$)
  - separate out variance component due to random effects, $\nu \sim nl(0, \sigma^2)$

conditional autoregression term (CAR)

- captures *structured* spatial variability
  - like a bookend to the *unstructured* random effects term ν
  - variation not accounted for by model or random effects term
- based on sets of 'spatial neighborhoods' (share a boundary)
  - $\mu_i \sim nl(\bar{\mu}_{\delta_i}, \tau_\mu / n_{\delta_i})$
  - where δ is a neighborhood of the i^th region and n_{δ_i} is the number of neighbors
  - the mean θ or risk in a neighborhood is normally distributed, with $\bar{\mu}$ the average of the μ 's in the neighborhood, and σ equal to the σ of the neighborhood μ 's divided by the number (δ) of spatial shapes in the neighborhood

coding CAR in WinBUGS

- use the car.normal() distribution
- requires an adjacency vector, weights, and list of number of neighbors for each region

```
b[1:J] ~ car.normal(adj[], weights[], num[], tau.b)
```

the updated (spatial) gamma-Poisson model

log-link, random effects and CAR

- $y_i \sim Pois(e_i \theta_i)$
- $ln(\theta) = \beta_i + \nu_i + \mu_i + \hat{\epsilon}$, where
- $\nu_i \sim nl(0, \tau_\nu)$
- $\mu_i \sim nl(\bar{\mu_{\delta_i}}, \tau_\mu / n_{\delta_i})$
- β_i is the intercept term and vector of regression coefficients for explanatory variables

spatial model statement

```
model{
for( i in 1 : m ) {
      y[i] ~ dpois(mu[i])
      mu[i] <- e[i] * rr[i]
      log(rr[i]) <- b0 +v[i] + h[i]  # h structured (spatial)
                                     # v unstructured(random)
      r[i]<-(y[i]-mu[i])             # r residual
      v[i]~dnorm(0,tau.v)      # normal prior on v
                  }
      b0~dnorm(0,tau.b0)      # normal prior on intercept

      h[1:m]~car.normal(adj[], weights[], num[], tau.h) # car term
      tau.b0~dgamma(0.001,0.001)     # gamma hyperpriors
      tau.v~dgamma(0.001,0.001)
      tau.h~dgamma(0.001,0.001)
     }
```

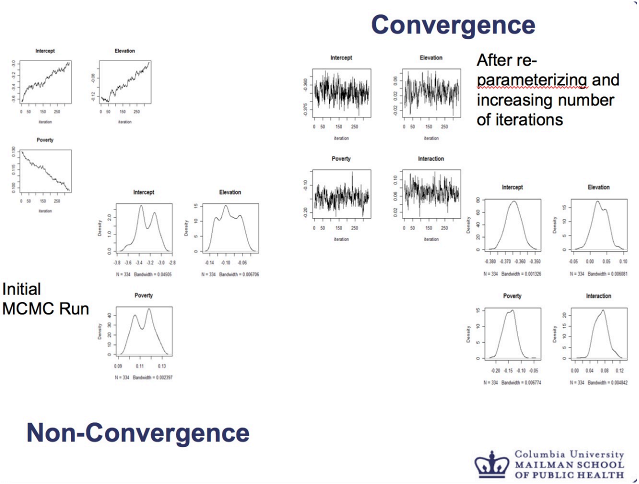
simulation in WinBUGS

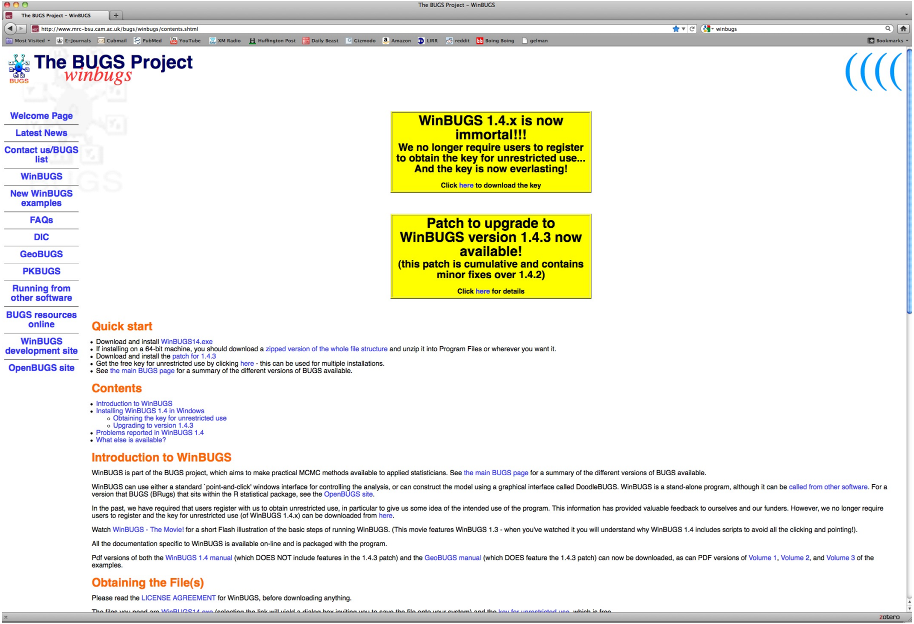
- Monte Carlo Markov Chain (MCMC)
  - most reasonably realistic problems framed in Bayesian way do not have simple or closed solutions
- WinBUGS
  - implementation of MCMC
  - chooses samples using either Gibb's (for which named) or Metropolis Hastings
  - R2WinBUGS interface
- sample space and convergence (there is no free ride)
  - MCMC comes with additional responsibilities
  - is sampler moving accross the space?
  - did the chain converge?

non-convergence

- not sampling from the posterior distribution so results not valid
- more informative priors for problematic variables
- drop or add variables
- $\star$ re-parameterize to improve sampling efficiency
    - center
    - standardize
    - log transform

assessing convergence





The BUGS Project – WinBUGS

http://www.mrc-bsu.cam.ac.uk/bugs/winbugs/contents.shtml

The BUGS Project
winbugs

- Welcome Page
- Latest News
- Contact us/BUGS list
- WinBUGS
- New WinBUGS examples
- FAQs
- DIC
- GeoBUGS
- PKBUGS
- Running from other software
- BUGS resources online
- WinBUGS development site
- OpenBUGS site

WinBUGS 1.4.x is now immortal!!!
We no longer require users to register to obtain the key for unrestricted use... And the key is now everlasting!
Click here to download the key

Patch to upgrade to WinBUGS version 1.4.3 now available!
(this patch is cumulative and contains minor fixes over 1.4.2)
Click here for details

Quick start

- Download and install WinBUGS14.exe
- If installing on a 64-bit machine, you should download a zipped version of the whole file structure and unzip it into Program Files or wherever you want it.
- Download and install the patch for 1.4.3
- Get the free key for unrestricted use by clicking here - this can be used for multiple installations.
- See the main BUGS page for a summary of the different versions of BUGS available.

Contents

- Introduction to WinBUGS
- Installing WinBUGS 1.4 in Windows
  - Obtaining the key for unrestricted use
  - Upgrading to version 1.4.3
- Problems reported in WinBUGS 1.4
- What else is available?

Introduction to WinBUGS

WinBUGS is part of the BUGS project, which aims to make practical MCMC methods available to applied statisticians. See the main BUGS page for a summary of the different versions of BUGS available.

WinBUGS can use either a standard `point-and-click' windows interface for controlling the analysis, or can construct the model using a graphical interface called DoodleBUGS. WinBUGS is a stand-alone program, although it can be called from other software. For a version that BUGS (BRugs) that sits within the R statistical package, see the OpenBUGS site.

In the past, we have required that users register with us to obtain unrestricted use, in particular to give us some idea of the intended use of the program. This information has provided valuable feedback to ourselves and our funders. However, we no longer require users to register and the key for unrestricted use (of WinBUGS 1.4.x) can be downloaded from here.

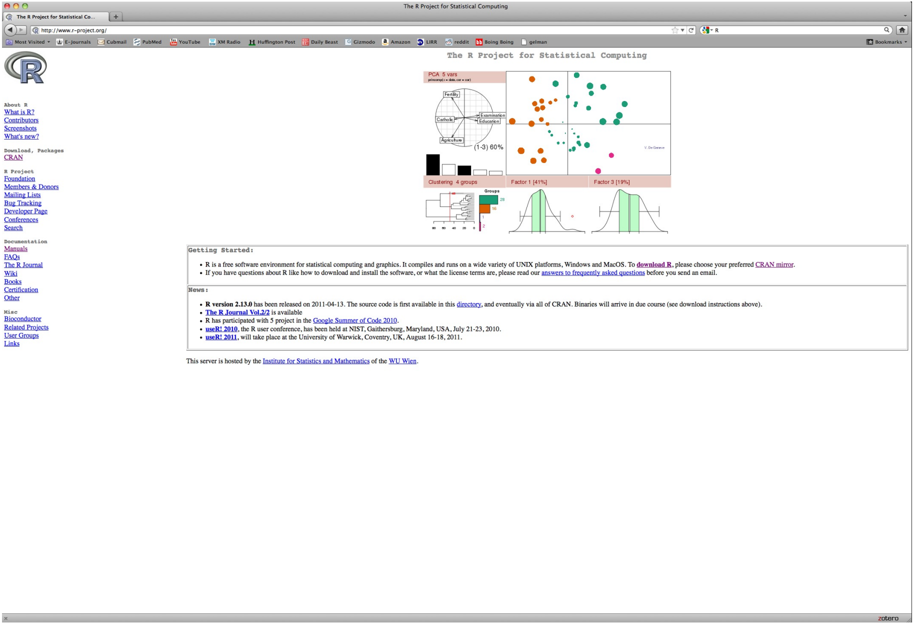
Watch WinBUGS - The Movie! for a short Flash illustration of the basic steps of running WinBUGS. (This movie features WinBUGS 1.3 - when you've watched it you will understand why WinBUGS 1.4 includes scripts to avoid all the clicking and pointing!).

All the documentation specific to WinBUGS is available on-line and is packaged with the program.

Pdf versions of both the WinBUGS 1.4 manual (which DOES NOT include features in the 1.4.3 patch) and the GeoBUGS manual (which DOES feature the 1.4.3 patch) can now be downloaded, as can PDF versions of Volume 1, Volume 2, and Volume 3 of the examples.

Obtaining the File(s)

Please read the LICENSE AGREEMENT for WinBUGS, before downloading anything.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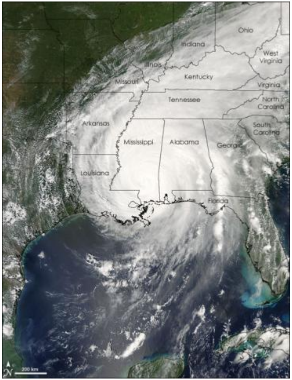
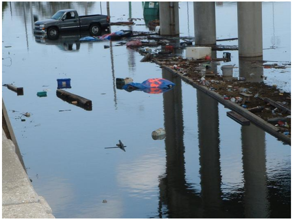
Agriculture
(1-3) 60%
Clustering 4 groups
Groups
Factor 1 [41%]
Factor 3 [19%]
Getting Started:
R is a free software environment for statistical computing and graphics. It compiles and runs on a wide variety of UNIX platforms, Windows and MacOS. To download R, please choose your preferred CRAN mirror.
If you have questions about R like how to download and install the software, or what the license terms are, please read our answers to frequently asked questions before you send an email.
News:
R version 2.13.0 has been released on 2011-04-13. The source code is first available in this directory, and eventually via all of CRAN. Binaries will arrive in due course (see download instructions above).
The R Journal Vol.2/2 is available
R has participated with 5 project in the Google Summer of Code 2010.
useR! 2010, the R user conference, has been held at NIST, Gaithersburg, Maryland, USA, July 21-23, 2010.
useR! 2011, will take place at the University of Warwick, Coventry, UK, August 16-18, 2011.
This server is hosted by the Institute for Statistics and Mathematics of the WU Wien.

Outline

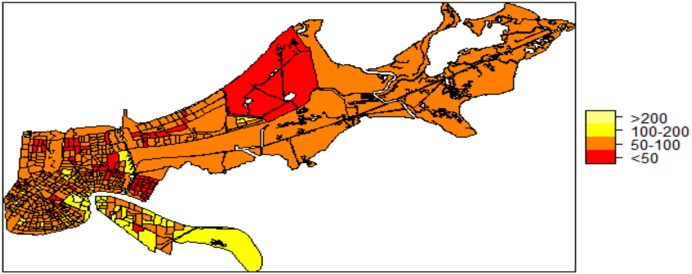




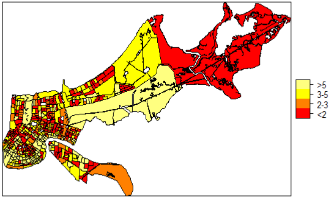
- repatriation measured by USPS delivery data
- June 2009 (observed) vs June 2005 (expected)
- θ_i estimates change in number of households receiving mail in a block group
- interested in *decreased* θ

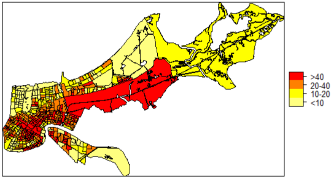
repatriation by SES and Geography

percent repatriation by block group



poverty and elevation choropleths





proportion below poverty level

elevation above sea level in meters

model statement

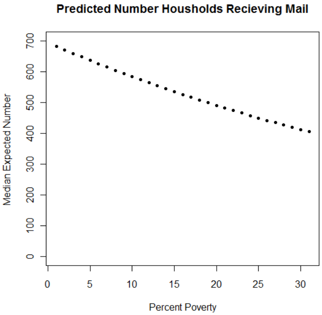
CAR, poverty, elevation, elev*pov

```
model{
for(i in 1:m ){
     y[i] ~ dpois(mu[i])
     mu[i] <- e[i] * rr[i]
     log(rr[i]) <- b0 + b1*((elevation[i]-3.7)/3.6)
                   + b2*((poverty[i]-28.4)/18.2)
                   + b3*((elevation[i]-3.7)/3.6)*(poverty[i]-28.4)/18.2))
                   + h[i]  # CAR term

     r[i]<-(y[i]-mu[i])             # r residual
     prob50[i]<-step(0.5-rr[i])     # step function exceedence
                     }

     h[1:m]~car.normal(adj[], weights[], num[], tau.h) # car term
     b0~dflat()                # priors
     b1~dnorm(0,0001)
     b2~dnorm(0,0001)
     b3~dnorm(0,0001)
     tau.h~dgamma(0.001,0.001)
    }
```

models compared using DIC (Bayesian analog of AIC)

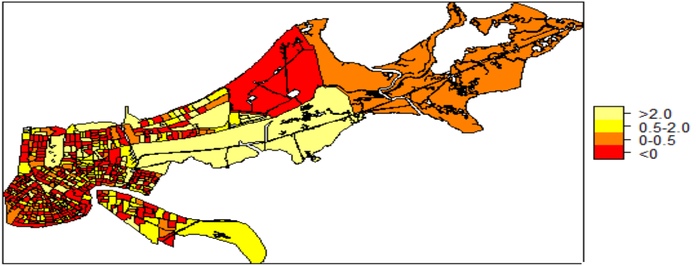
some numeric results

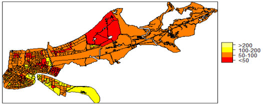
parameter	mean	credible interval
intercept	-0.36	(-0.37, -0.35)
elevation	0.029	(-0.009, 0.07)
poverty	-0.14	(-0.20, -0.10)
elev*pov	0.07	(0.04, 0.11)



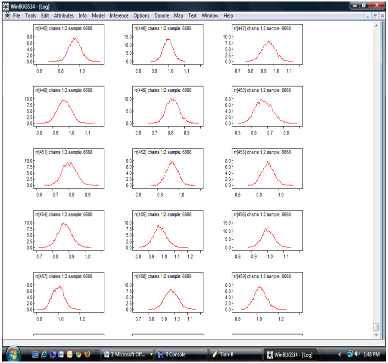
smoothed repatriation estimates

adjusted for poverty and elevation



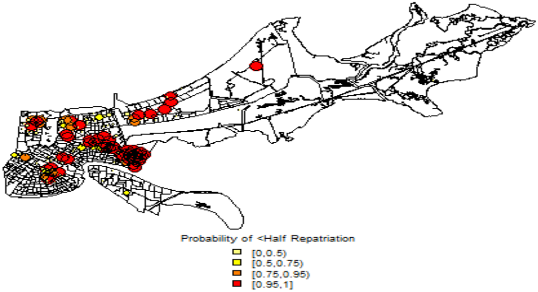


posterior probability of θ_i



can be used to map *exceedence*, or probablity greater than x

exceedence map



Outline

the role of epidemiology in disasters

- socioeconomics, behavior and geography intersect and interact in complex ways to mediate disaster risk
- the role of epidemiology is to disintangle these competing and interacting risk to identify ways to mitigate and control the societal and health effects of disasters
- spatial analysis can extend epidemiologic methods following disasters
  - Bayesian hierarchical modeling a great tool to explain spatial patterning of health outcomes and risk
  - but it comes with some additional analytic baggage (prior specification, convergence, interpretation)

credit where credit is due...

David Abramson, PhD
National Center for
Disaster Preparedness

Andrew Lawson, PhD
Medical University of
South Carolina