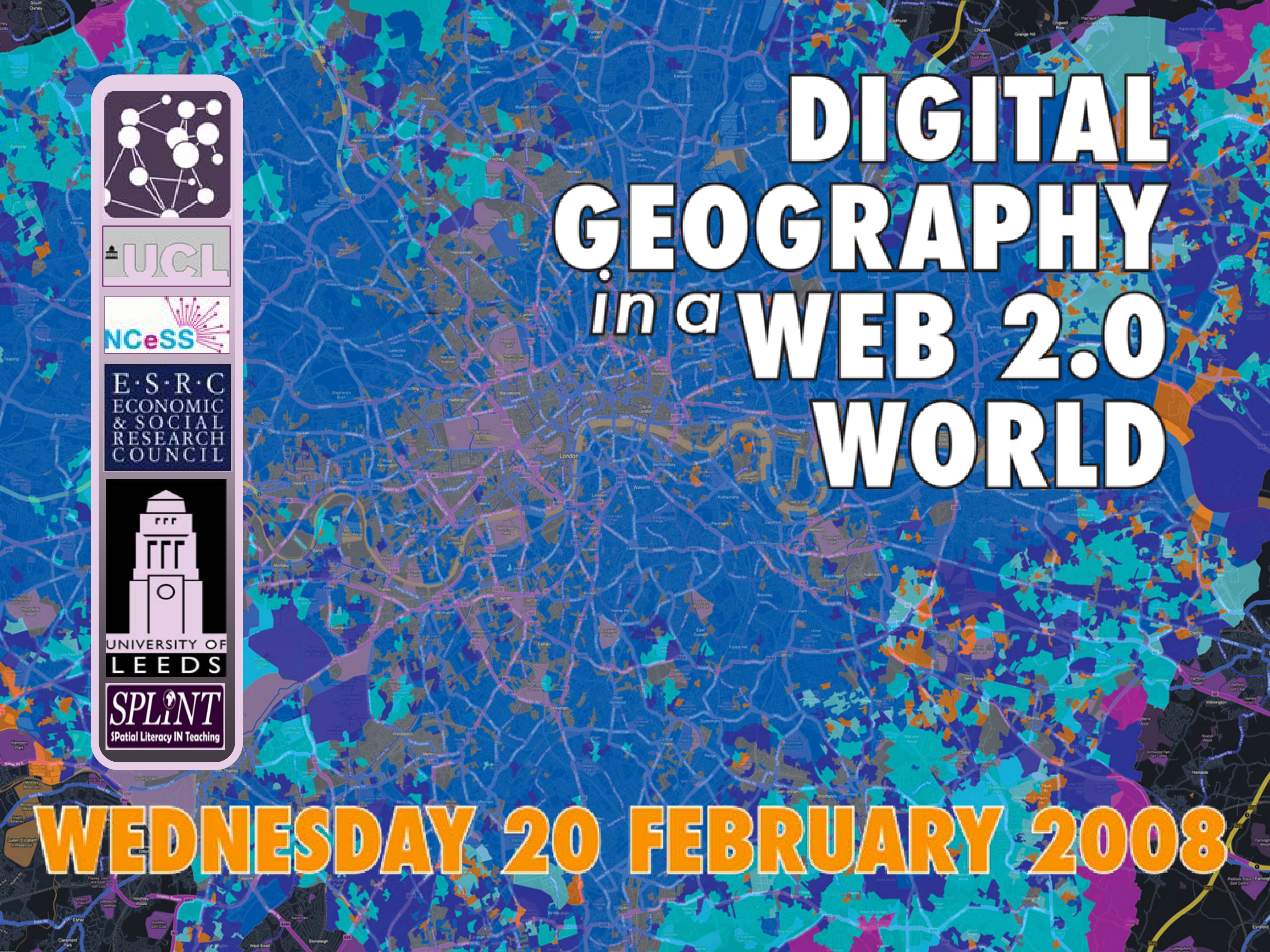

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DIGITAL GEOGRAPHY *in a* WEB 2.0 WORLD

WEDNESDAY 20 FEBRUARY 2008

GEOGRAPHICAL STATISTICS & THE GRID

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(Universities of Bristol, Leicester & Lancaster)

http://rose.bris.ac.uk

OUTLINE

- About Geographically Weighted Regression (GWR)
  - Chris Brunsdon, Department of Geography, University of Leicester
  - cb179@le.ac.uk

- An example to illustrate a problem of using GWR with large datasets
- ‘The solution’
  - Rich Harris, School of Geographical Sciences, University of Bristol
  - rich.harris@bris.ac.uk

LOCAL VS GLOBAL STATISTICS

- Global
  - similarities across space
  - single-valued statistics
  - non-mappable
  - GIS “unfriendly”
  - search for regularities
  - aspatial

- Local
  - differences across space
  - multi-valued statistics
  - mappable
  - GIS “friendly”
  - search for exceptions
  - spatial

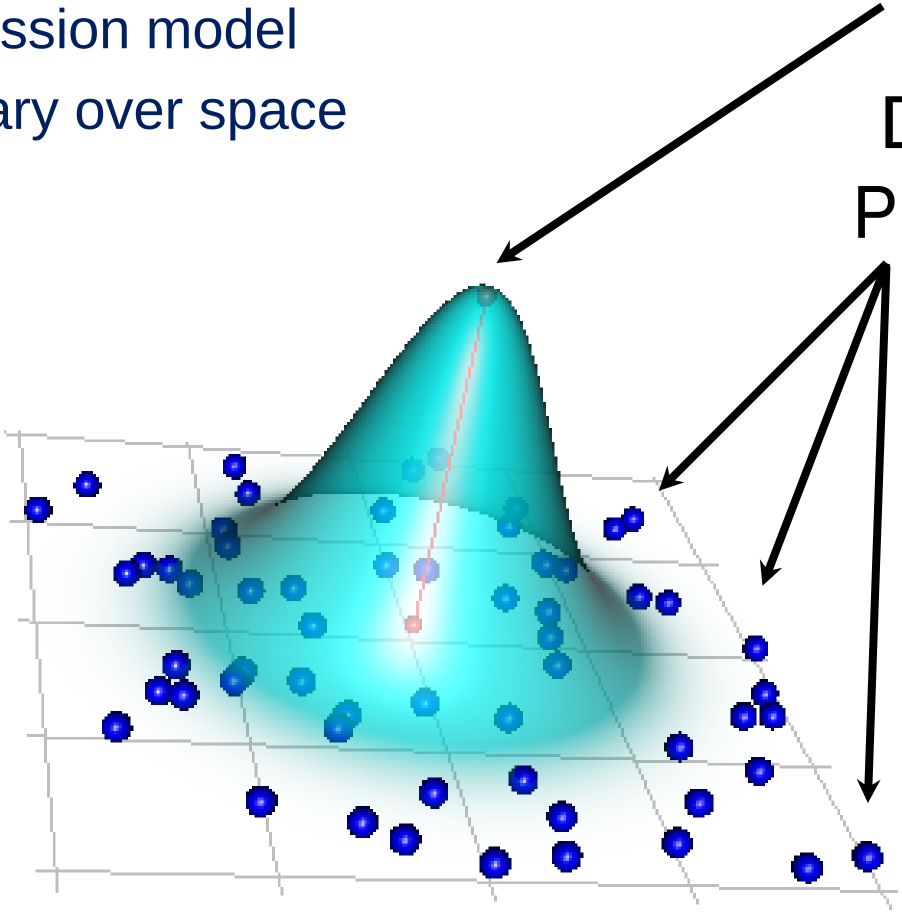
- Local statistics are spatial disaggregations of global statistics

WHY MIGHT RELATIONSHIPS VARY SPATIALLY?

- Sampling variation
- Relationships intrinsically different across space e.g. differences in attitudes, preferences or different administrative, political or other contextual effects produce different responses to the same stimuli.
- Model misspecification - suppose a global statement can ultimately be made but models not properly specified to allow us to make it. Local models good indicator of how model is misspecified.

GEOGRAPHICALLY WEIGHTED REGRESSION (GWR)

- What is it?
  - Extension of regression model
  - Allows model to vary over space
- How it works...



Regression Point

Data Points

IN GWR WE CAN ALSO…

- estimate local standard errors
- calculate local leverage measures
- perform tests to assess the significance of the spatial variation in the local parameter estimates
- perform tests to determine if the local model performs better than the global one

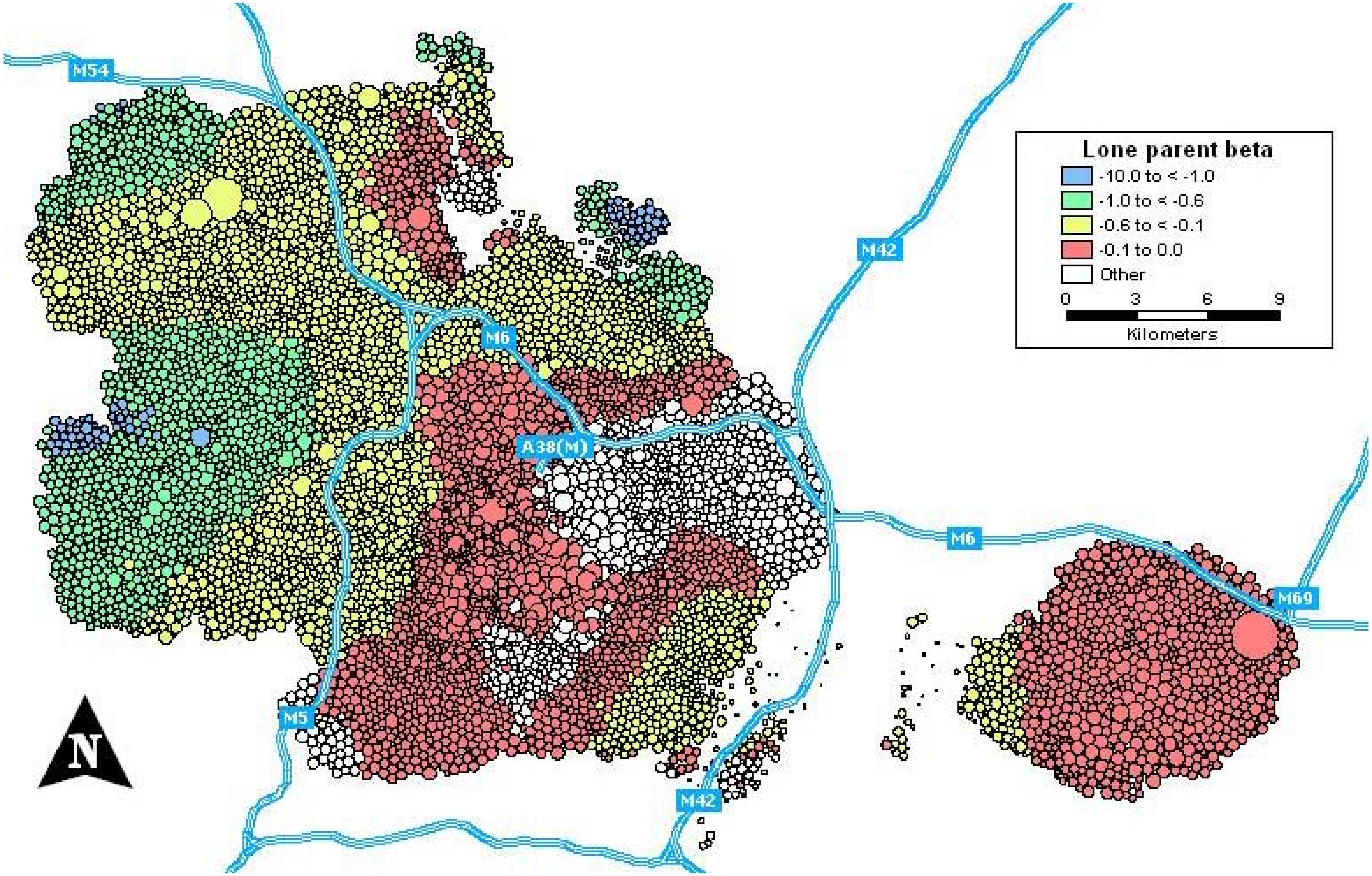
BUT

- Computationally very demanding
- Need to fit weighted regression models in several places
- Sometimes not viable on a single computer
- How do we address this problem?

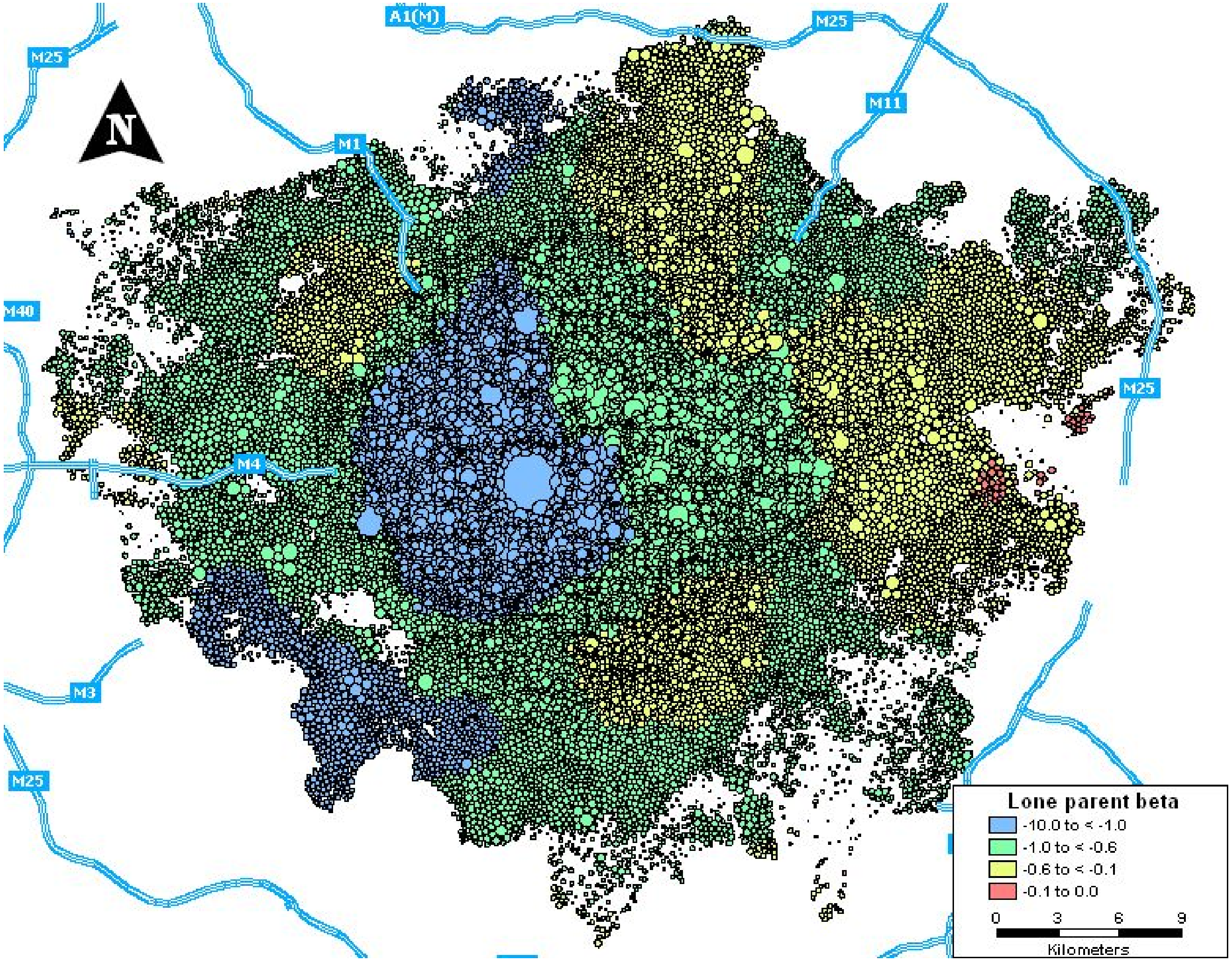
EXAMPLE

- Y: Proportion of households without a car
- X_1: Proportion of persons of working age unemployed
- X_2: Proportion of households in public housing
- X_3: Proportion of households that are lone parent households
- X_4: Proportion of persons 16 or above that are single
- X_5: Proportion of persons that are “white British”
- n = 165,665

SPATIAL VARIATION IN THE LONE PARENT COEFFICIENT (WEST MIDLANDS)



SPATIAL VARIATION IN THE LONE PARENT COEFFICIENT (LONDON)



SCALING PROBLEMS

- There are n regression models
- But actually there are many more:
  - n× g
  - g is the number of iterations to optimize the bandwidth, b
- And you also need to calculate the distance matrix, D: (n^2)

TAKES A LONG TIME!

- If n = 100,000, on a single processor
  - Would take about half a day to calculate D
  - Would take about a fortnight to find b
- But GWR is intended for exploratory analysis!
- The main bottleneck is the calibration of b
  - Because the regression calculations are O(n^3), the distance calculations are O(n^2)

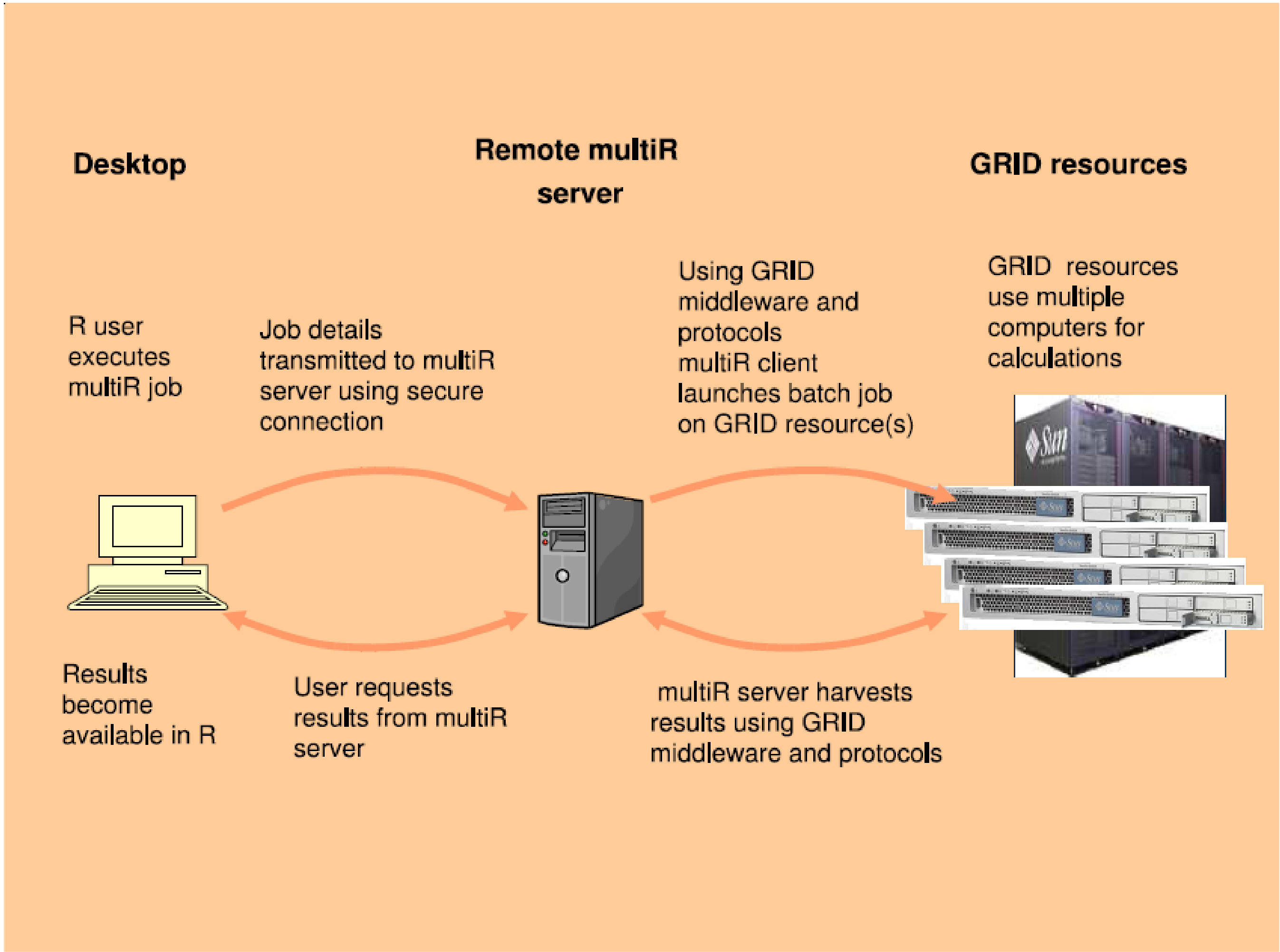
FORTUNATELY

- The regression models are fitted entirely independent of each other. The results are pooled and compared *at the end*.
- The process is sequential but it can also be embarrassingly parallel
  - For GWR, the (distance-weighted regression) function stays the same, only the data are changing.
  - Each spatial subset is handled separately from the next.
- True of many methods of spatially localized analysis
- Suitable for a computational grid
  - The UK's National Grid Service (NGS)

MULTIR AND PARALLEL R

- R is a free software environment for statistical computing and graphics
  - http://www.r-project.org/
- There is an implementation of GWR in R
  - The spgwr package
- In R, there is a method to invoke a function a number of times with varying argument values
  - sapply
- The idea is to invoke the function on different processors running on the NGS.
- multiR (thanks to Daniel Grose) is both an ‘add in’ to R and a server (currently at Lancaster) which provides middleware between desktop R and the NGS.

THE THREE TIER CLIENT/SERVER ARCHITECTURE EMPLOYED BY MULTIR



Desktop

Remote multiR server

GRID resources

R user executes multiR job

Job details transmitted to multiR server using secure connection

Using GRID middleware and protocols multiR client launches batch job on GRID resource(s)

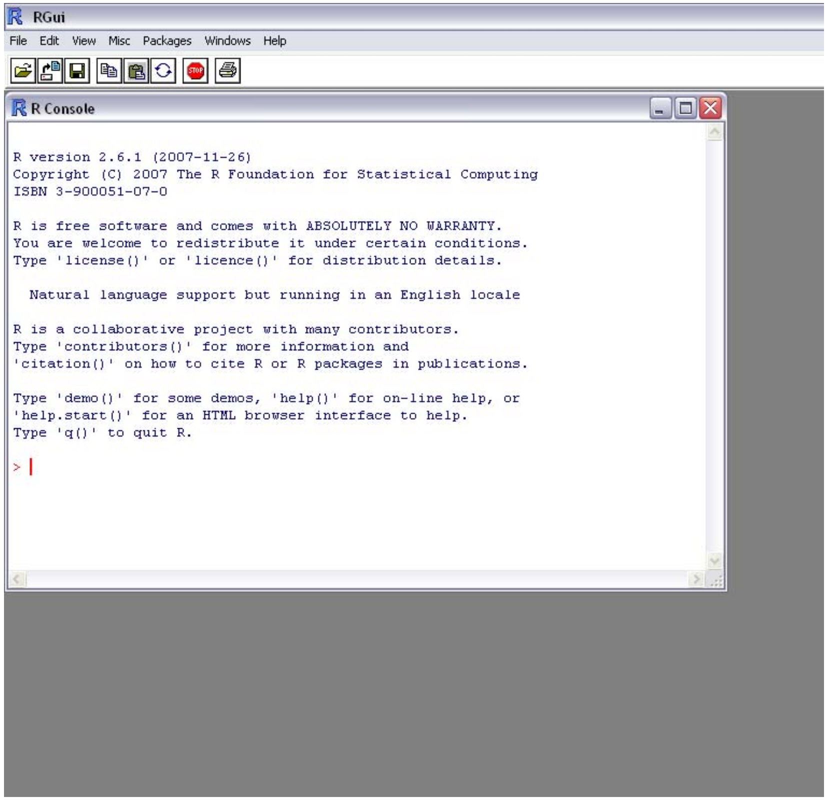
GRID resources use multiple computers for calculations

Results become available in R

User requests results from multiR server

multiR server harvests results using GRID middleware and protocols

THIS IS R (IN WINDOWS)



```
R version 2.6.1 (2007-11-26)
Copyright (C) 2007 The R Foundation for Statistical Computing
ISBN 3-900051-07-0

R is free software and comes with ABSOLUTELY NO WARRANTY.
You are welcome to redistribute it under certain conditions.
Type 'license()' or 'licence()' for distribution details.

  Natural language support but running in an English locale

R is a collaborative project with many contributors.
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'citation()' on how to cite R or R packages in publications.

Type 'demo()' for some demos, 'help()' for on-line help, or
'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.

> |
```

- Available free from
  - http://cran.r-project.org/
- We have a tutorial
  - www.esrcsocietytoday.ac.uk
  - type ‘Grid Enabled Spatial Regression Models’ into the Search

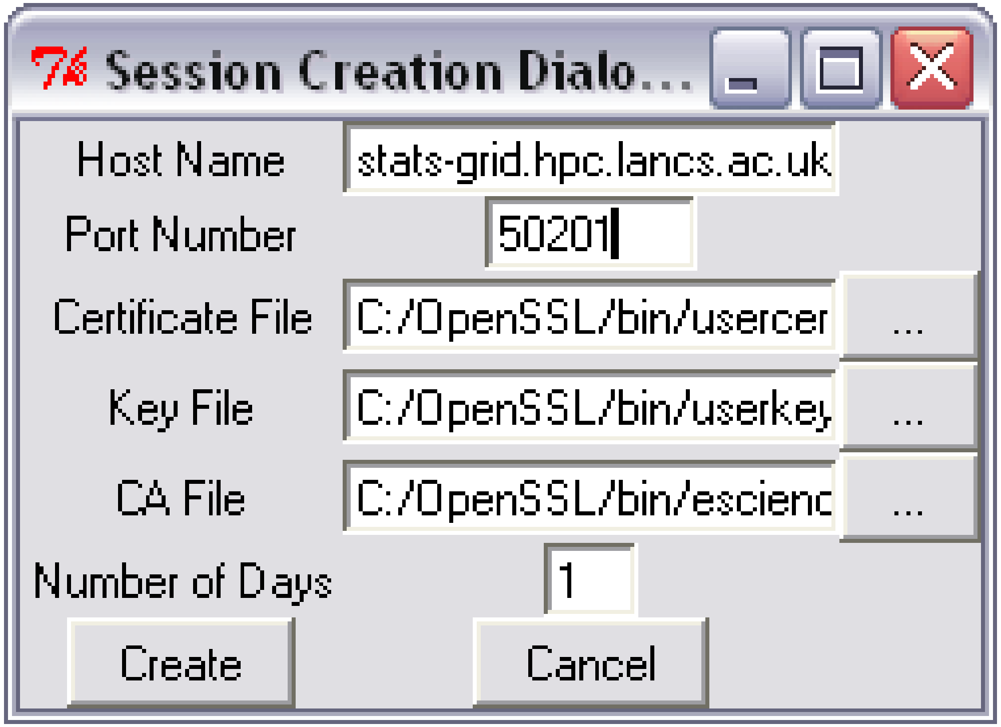
FITTING A GWR MODEL IN R

```
> library(spgwr)
> load("carsmsoa.RData")
> names(car.msoa)
[1] "Name"      "Borough"  "ProfMan"  "Renting"
  "HHNoCar"  "Easting"  "Northing"
> coords = cbind(car.msoa$Easting,
  car.msoa$Northing)
> bandwidth = gwr.sel(HHNoCar ~ Renting, data =
  car.msoa, coords)
Bandwidth: 25571.63 CV score: 4.278767
Bandwidth: 41334.45 CV score: 4.373939
…
Bandwidth: 1467.076 CV score: 2.922873
> gwr.model1 = gwr(HHNoCar ~ Renting, data =
  car.msoa, coords, bandwidth)
```

FITTING A GRID RUN GWR MODEL

```
> library(spgwr.dist)
> load("D:\\Data\\GWR-
  Workshop\\Data\\Exercises\\carsmsoa.RData")
> names(car.msoa)
[1] "Name"      "Borough"  "ProfMan"  "Renting"
  "HHNoCar"  "Easting"  "Northing"
> coords = cbind(car.msoa$Easting,
  car.msoa$Northing)
> session = multiR.session.dlg()
> bandwidth = gwr.sel.dist(session, HHNoCar ~
  Renting, data = car.msoa, coords,
  max.processors = 50)
> gwr.model2 = gwr.dist(session, HHNoCar ~
  Renting, data = car.msoa, coords, bandwidth,
  max.processors = 50)
```

'THE SESSION'



Session Creation Dialo...

Host Name: stats-grid.hpc.lancs.ac.uk

Port Number: 50201

Certificate File: C:/OpenSSL/bin/usercer

Key File: C:/OpenSSL/bin/userkey

CA File: C:/OpenSSL/bin/escienc

Number of Days: 1

- It is loading and dealing with the various security certificates that are needed to use the NGS

OBTAINING THE CERTIFICATES

- This is required for all NGS services
- User certificates:
  - Apply at https://ca.grid-support.ac.uk/
    - The certificate is issued for a web browser: the one you apply from needs to be the same as the one which will receive it.
  - Then need to:
    - Export the certificate from the browser
    - use OpenSSL toolkit to convert into two files (the certificate and its **key file**) and to generate a **proxy certificate**
    - See www.grid-support.ac.uk/content/view/67/184/
  - You also need to apply for an NGS account
    - http://www.grid-support.ac.uk/content/view/221/171/
- CA certificate:
  - Download from http://www.grid-support.ac.uk/content/view/182/184/

CONCLUSIONS AND CAVEATS

- There is no point in using Grid GWR for small data sets (e.g. n < 1000)
- And you should not expect instant results with large datasets (it still takes a second or so for each regression fit and you don’t have that many processors)
- You cannot presently disconnect from R when running a Grid GWR but that should follow (and return later to collect the results)
- The software are still being tested

POTENTIAL

- multiR is more generic than GWR
- Imagine

```
function1 = function(its_parameters) {
  what it does
}
```

- Then

```
some_results = multiR(session, function1,
  list=(the_data))
```

- In other words, the function is running in parallel on the NGS
- Applications include spatial statistics, geostatistics, ‘hot spot analysis’, simulation, etc.

ACKNOWLEDGMENTS

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- Particular thanks to the Centre for e-Science, Lancaster University