Spatial Perspectives for the Globe

Michael F. Goodchild
University of California
Santa Barbara

Outline

- A brief introduction to GIS
  - alternative world views
- Why a spatial perspective?
- Why a global perspective?

Location as attribute

- The data table
  - Census summary table
- What value is location as an explanatory variable?
- Linking the table to a boundary file
  - enabling maps of summary data

Tract	Pop	Location	Shape
1	3786	*x*,*y*	
2	2966	*x*,*y*	
3	5001	*x*,*y*	
4	4983	*x*,*y*	
5	4130	*x*,*y*	
6	3229	*x*,*y*	
7	4086	*x*,*y*	
8	3979	*x*,*y*	

Abstraction of geographic space

- Cartograms

- Invariance under rotation, displacement
- Reconstruction from a distance matrix
- Reconstruction from ranked distances
  - ordered metric data (Coombs)

Space as a matrix

- ***W*** where w_{ij} is some measure of interaction
  - adjacency
  - decreasing function of distance
  - invariant under rotation, displacement
  - readily obtained from a GIS

Applications of the *W* matrix

- Spatial regression
  - add spatially lagged terms weighted by ***W***
  - Anselin's SPACESTAT, GeoDa
- Moran and Geary indices of spatial dependence

$$c = \frac{(n-1)\sum_i \sum_j w_{ij}(x_i - x_j)^2}{2\sum_i \sum_j w_{ij} \sum_i (x_i - a)^2}$$

The location-as-attribute world view

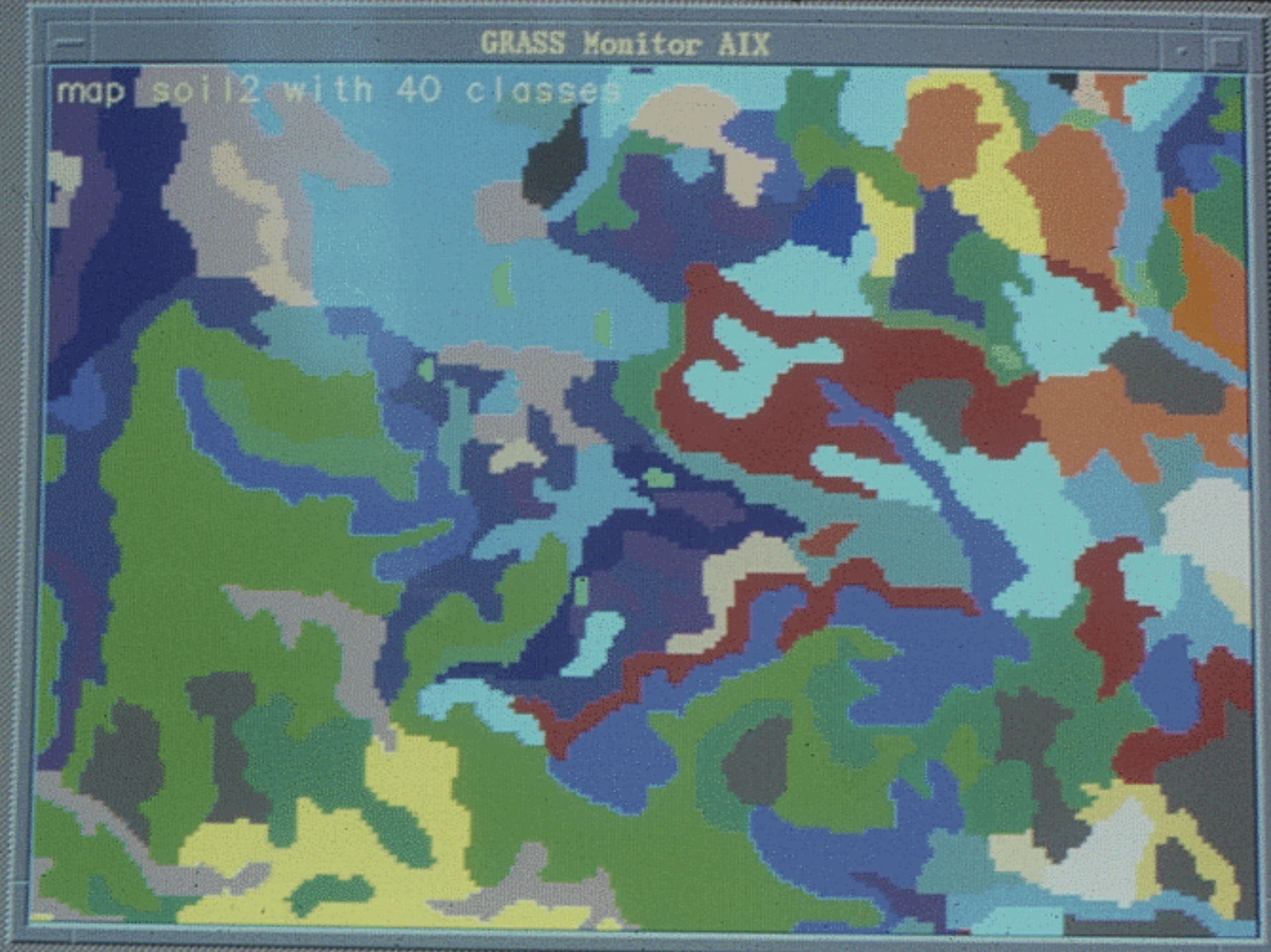
- Objective: scientific explanation, understanding of social processes
  - is location an explanatory factor?
- Relative location as expressed in the ***W*** matrix
  - a surrogate for spatial interaction
  - reflecting costs of transport, probability of interaction and acquaintance, probability of migration or travel, probability of seed dispersal

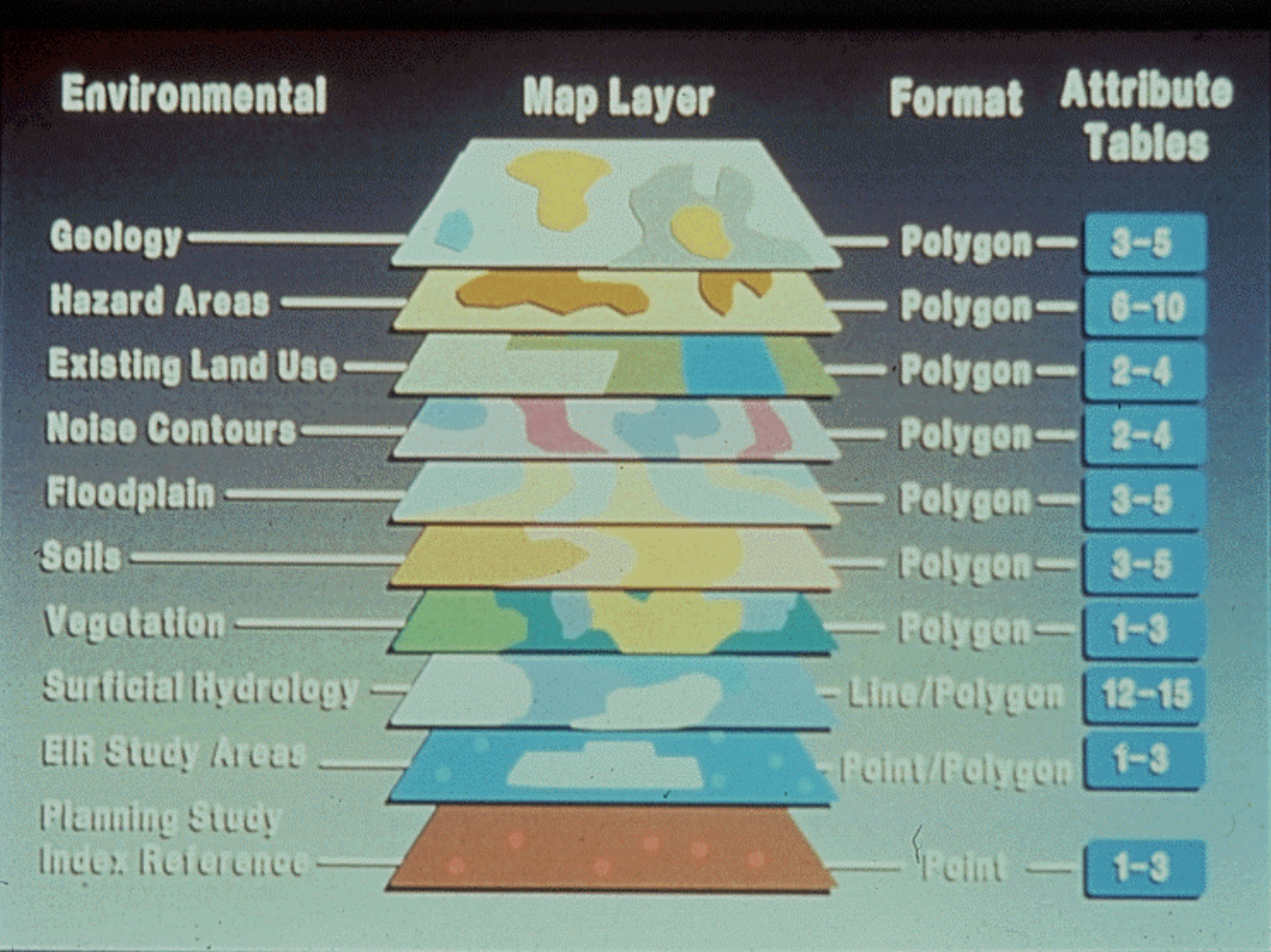
Geographic information systems

- Systems to acquire, store, transform, analyze, display, share, archive geographic information
- Geographic information
  - information about the specific characteristics of places on or near the Earth's surface
  - <***x***,***z***> where ***x*** is a location in space-time and ***z*** is some set of general properties

Origins of GIS

- The Canada Geographic Information System
  - circa 1965
  - support for the Canada Land Inventory
  - $20 million investment by the Government of Canada
  - justified by accurate cost-benefit analysis


GRASS Monitor AIX
map soil2 with 40 classes

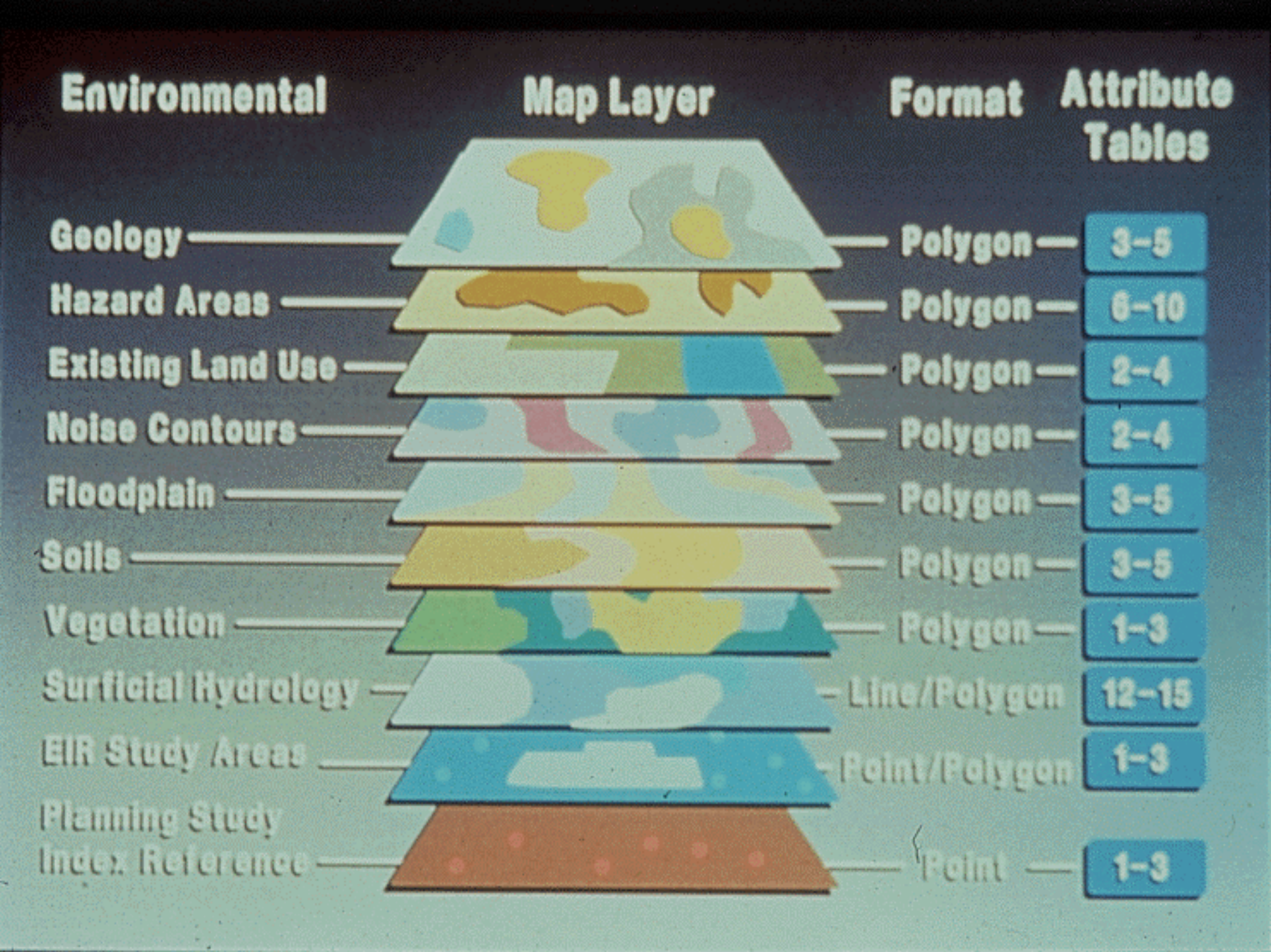

Environmental
Map Layer
Format
Attribute Tables
Geology
Hazard Areas
Existing Land Use
Noise Contours
Floodplain
Soils
Vegetation
Surficial Hydrology
EIR Study Areas
Planning Study Index Reference
Polygon
Polygon
Polygon
Polygon
Polygon
Polygon
Polygon
Line/Polygon
Point/Polygon
Point
3–5
6–10
2–4
2–4
3–5
3–5
1–3
12–15
1–3
1–3

Objectives of GIS

- Mapping and inventory
  - representing the contents of the Earth's surface
  - using space (and time) as the organizing dimensions
- Design
  - formulation, evaluation of future scenarios
- Support for science
  - search for pattern, anomalies, hypotheses, explanation
  - integrating layers of data
  - geographic context

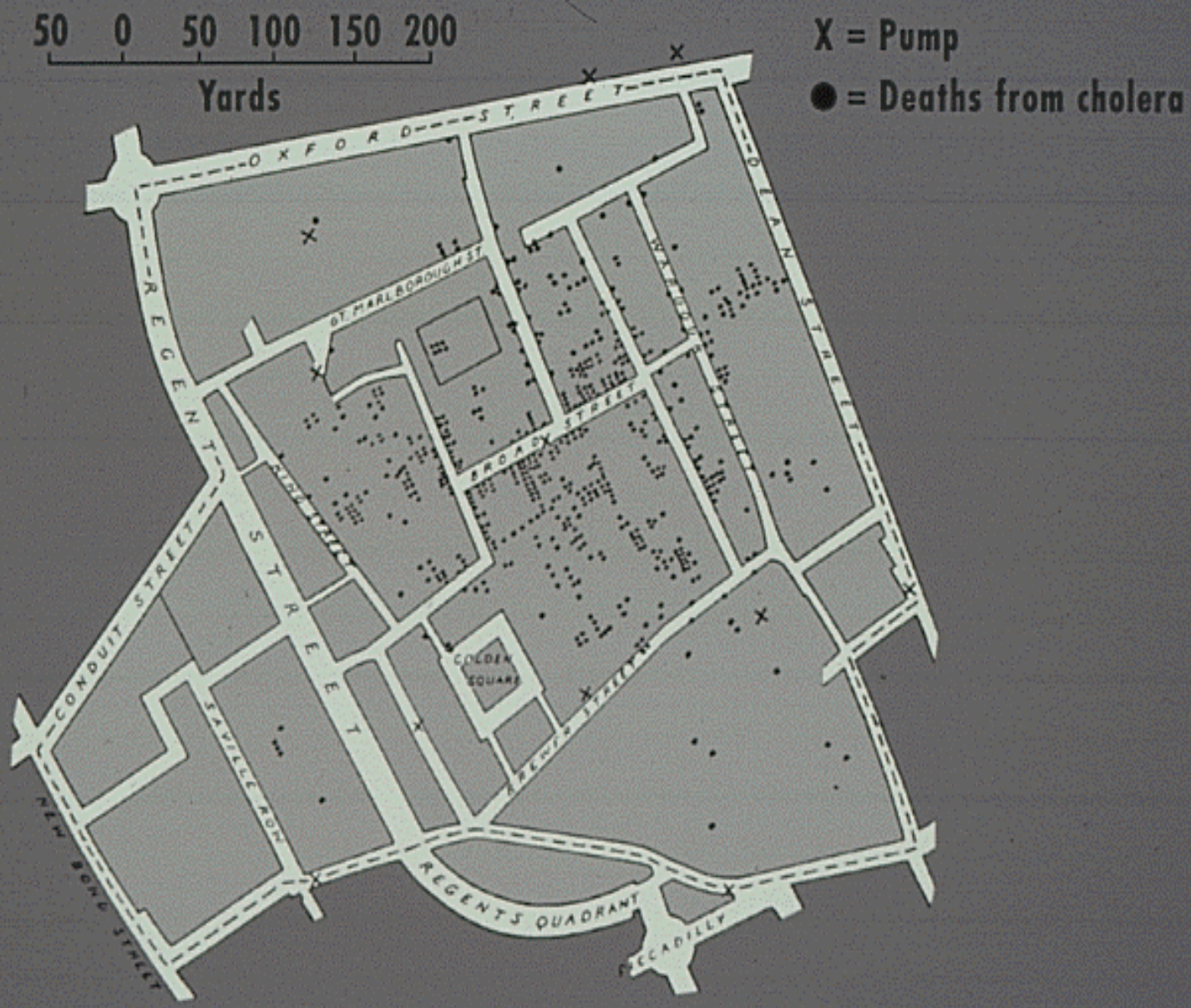
General principles: 1. Integration

- Linking data through common location
  - the layer cake
- Linking processes across disciplines
  - spatially explicit processes
  - e.g. economic and social processes interact at common locations


Environmental
Map Layer
Format
Attribute Tables
Geology
Hazard Areas
Existing Land Use
Noise Contours
Floodplain
Soils
Vegetation
Surficial Hydrology
EIR Study Areas
Planning Study Index Reference
Polygon
Polygon
Polygon
Polygon
Polygon
Polygon
Polygon
Line/Polygon
Point/Polygon
Point
3–5
6–10
2–4
2–4
3–5
3–5
1–3
12–15
1–3
1–3

2. Spatial analysis

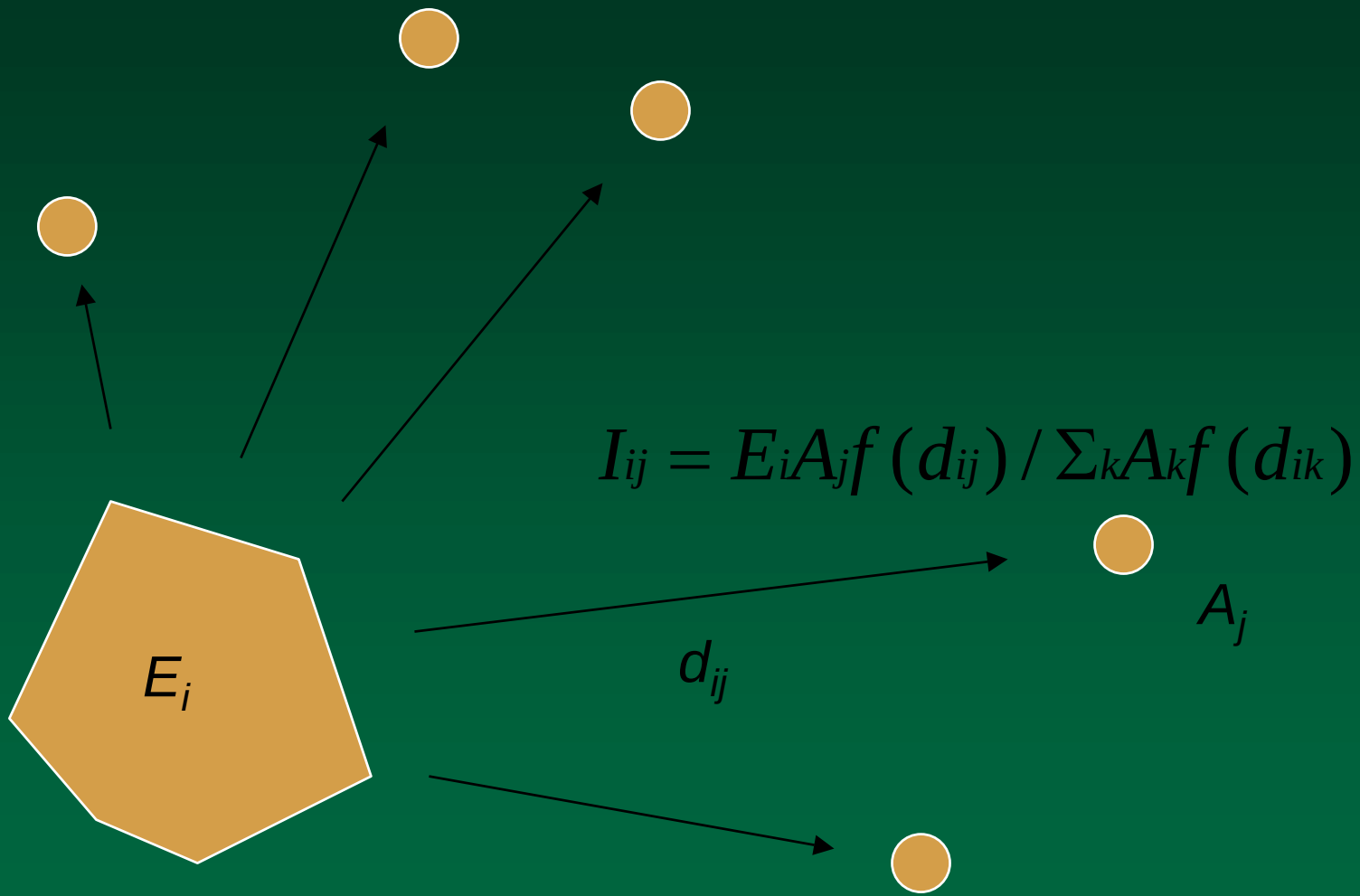
- Social data collected in cross-section
  - longitudinal data are difficult to construct
- Cross-sectional perspectives are rich in context
  - can never confirm process
  - though they can perhaps falsify
  - useful source of hypotheses, insights



The Snow Map of Cholera Incidence in the Area of Broad Street, London, in 1854.
The contaminated water pump is located at the center of the map, just to the right of the D in BROAD STREET.

3. Spatially explicit theory

- Theory that is not invariant under relocation
- Spatial concepts (location, distance, adjacency) appear explicitly
- Can spatial concepts ever *explain*, or are they always surrogates for something else?


$I_{ij} = E_i A_j f(d_{ij}) / \Sigma_k A_k f(d_{ik})$
A_j
d_{ij}
E_i

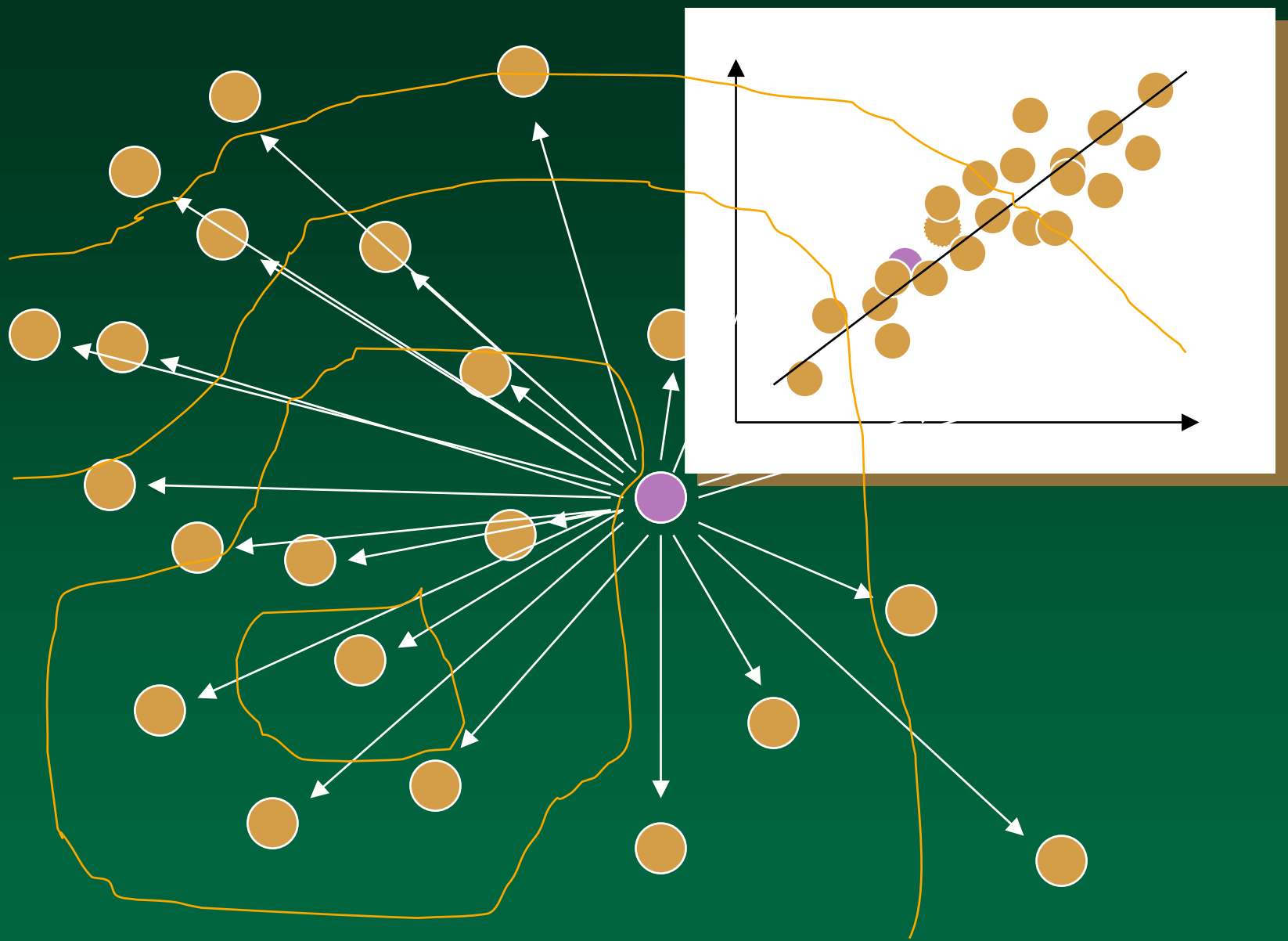
4. Place-based analysis

- Nomothetic - search for general principles
- Idiographic - description of unique properties of places
- An old debate in Geography

The Earth's surface

- Uncontrolled variance
- There is no average place
- Results depend explicitly on bounds
- Places as samples
- Consider the model:

  $y = a + bx$



5. Knowledge and policy

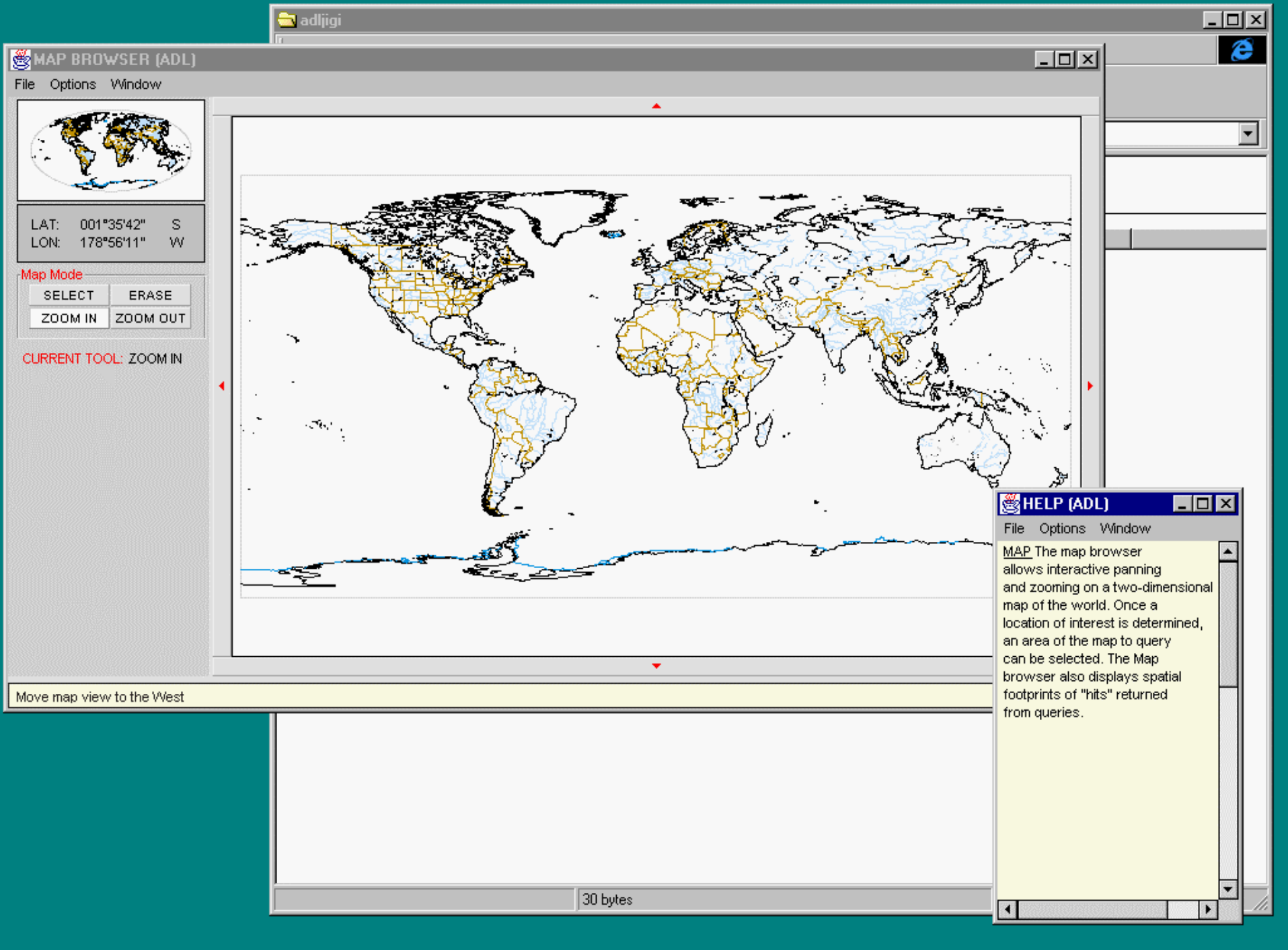
- Policy requires the projection of general knowledge in spatial context
  - the implications of this process in this location
  - alternative futures visualized under local circumstances
- GIS combines the general (processes, models, algorithms) with the specific (database of local details)

6. Place-based search

- Location as an organizing dimension to information
  - much information can be georeferenced
  - much more than maps and images
- The Geolibrary
  - what have you got about *there*?
  - impossible physically, feasible digitally

Prototype geolibraries

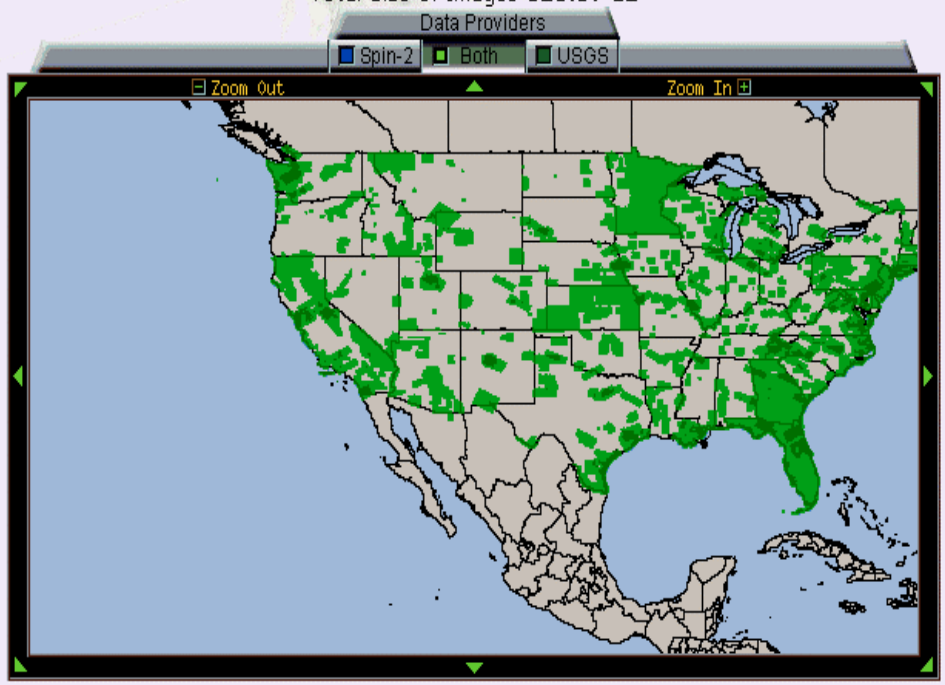
- National Geospatial Data Clearinghouse
  - *www.fgdc.gov*
- Microsoft's Terraserver
  - *terraserver.microsoft.com*
- Alexandria Digital Library
  - *alexandria.ucsb.edu*


adljigi
MAP BROWSER (ADL)
File Options Window
LAT: 001°35'42" S
LON: 178°56'11" W
Map Mode
SELECT
ERASE
ZOOM IN
ZOOM OUT
CURRENT TOOL: ZOOM IN
Move map view to the West
HELP (ADL)
File Options Window
MAP The map browser allows interactive panning and zooming on a two-dimensional map of the world. Once a location of interest is determined, an area of the map to query can be selected. The Map browser also displays spatial footprints of "hits" returned from queries.
30 bytes

Contents:

Find a Spot on Earth by Place Name | Map Search | Geo Coordinates

Database Rows covering shaded area **149,757,510**
Total Size of Images **628.67 GB**



Coverage graphic courtesy of the United States Geological Survey.

The green shading on the map identifies the locations covered by images stored in the Microsoft® TerraServer database. Click on a country or state/province you are interested in viewing.

The following contributors made TerraServer possible: Microsoft, Compaq, StorageWorks, USGS,, SPIN-2, Legato, and StorageTek.

Global GIS

- Resigning from the Flat Earth Society
- Enabled by 3D graphics
  - specialized data structures
- Enabled by improved data supply
  - improved tools for search, discovery, integration
  - Digital Earth

A grand challenge of GIS

- To create useful, comprehensive digital representations of the enormous complexity of the Earth's surface in the limited space of a digital store, using a binary alphabet

“Imagine, for example, a young child going to a Digital Earth exhibit at a local museum. After donning a head-mounted display, she sees Earth as it appears from space. Using a data glove, she zooms in, using higher and higher levels of resolution, to see continents, then regions, countries, cities, and finally individual houses, trees, and other natural and man-made objects. Having found an area of the planet she is interested in exploring, she takes the equivalent of a ‘magic carpet ride’ through a 3-D visualization of the terrain.”

Is Digital Earth feasible?

- 500,000,000 sq km
  - 5 million at 10km resolution
  - 500,000,000,000,000 at 1m resolution

500,000,000,000,000

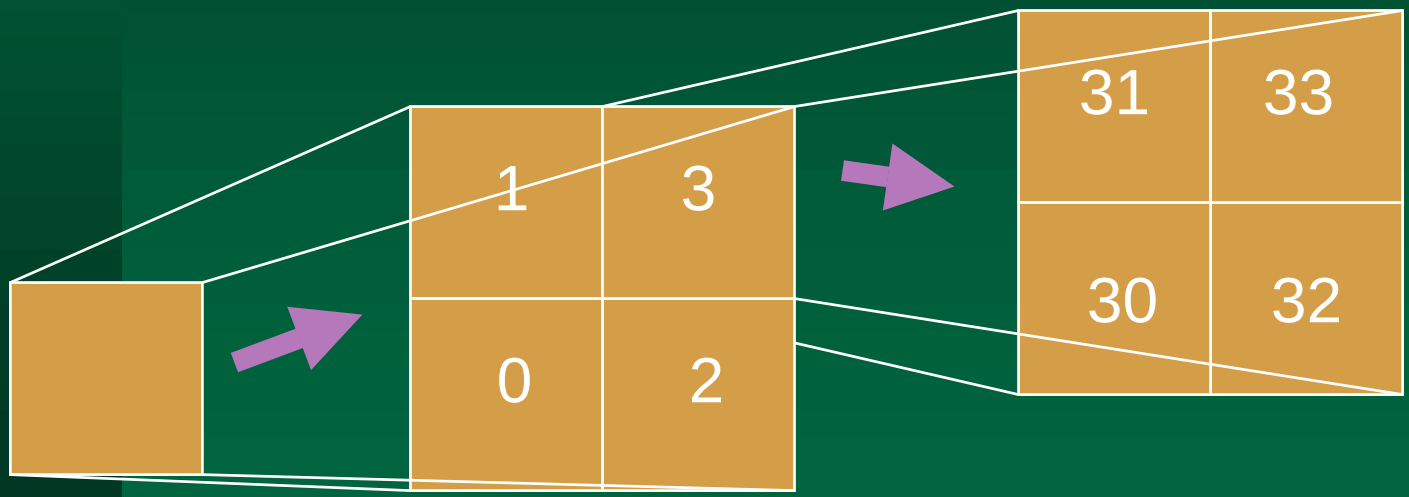
1,584 working years

The LS ratio

- Computer screen - 1000
- Digital camera - 1500
- Remotely sensed scene - 3000
- Paper map - 5000
- Dimensionless
- $Log_{10}L/S$ in range 3-4
- Human eye - 10,000

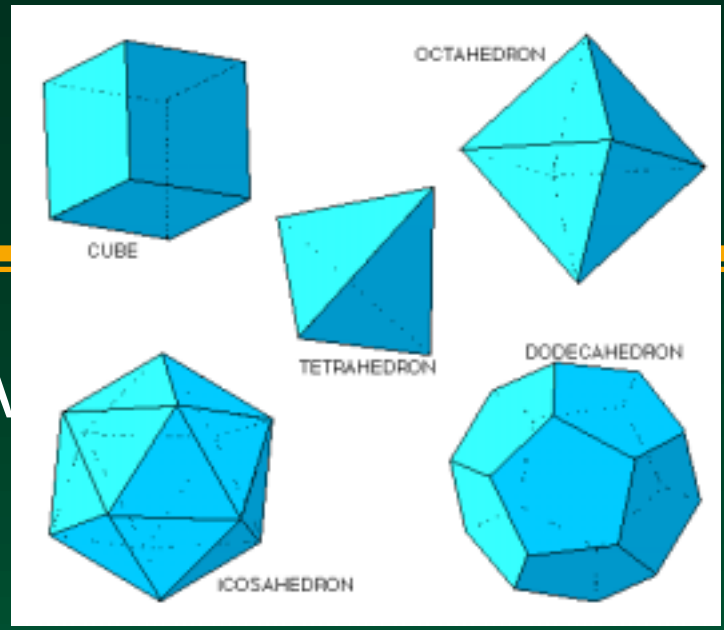
The quadtree

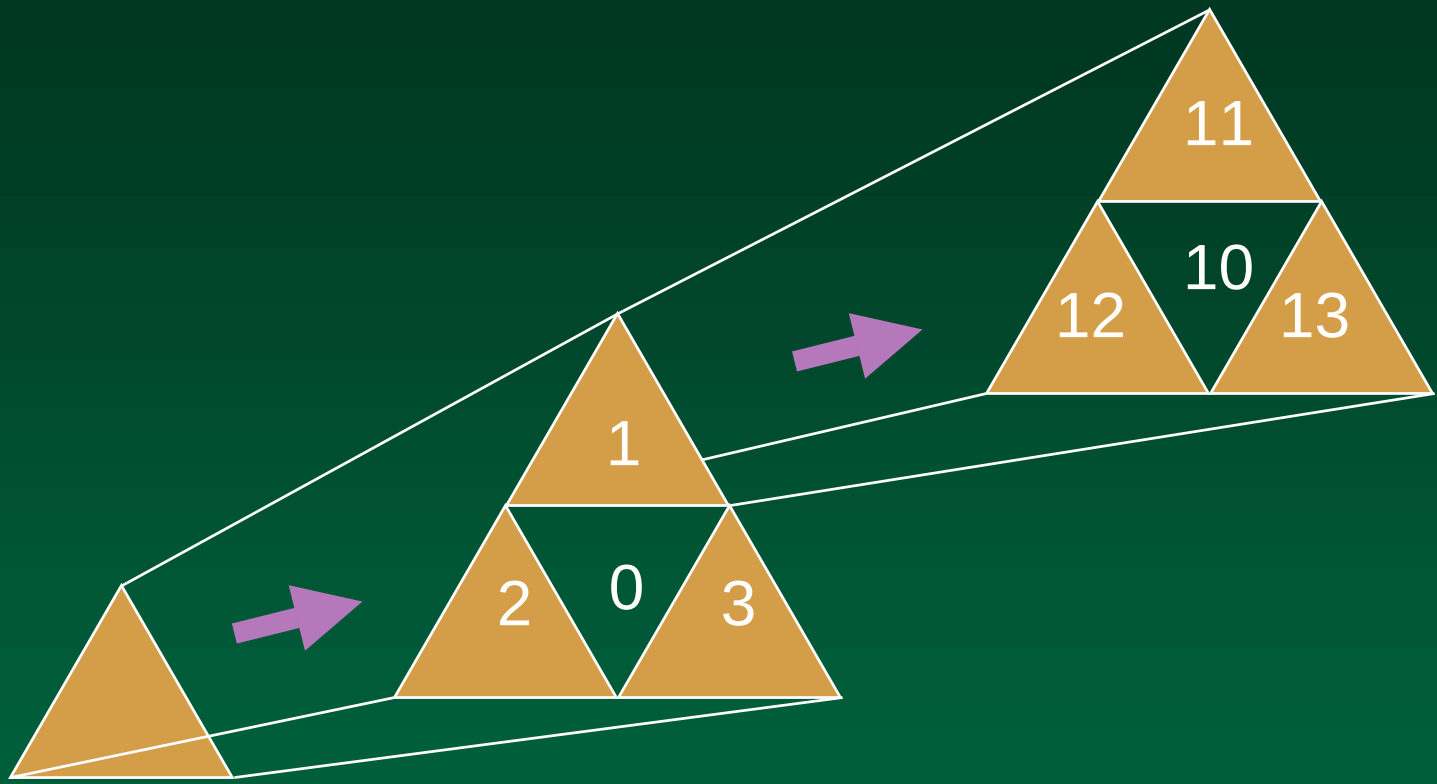
- Recursive subdivision
  - variable depth depending on local detail



Grids on the globe

- Impossible to tile a curv
  squares
- Five Platonic solids
  - tetrahedron: 4 triangles
  - cube: 6 squares
  - octahedron: 8 triangles
  - dodecahedron: 12 pentagons
  - icosahedron: 20 triangles





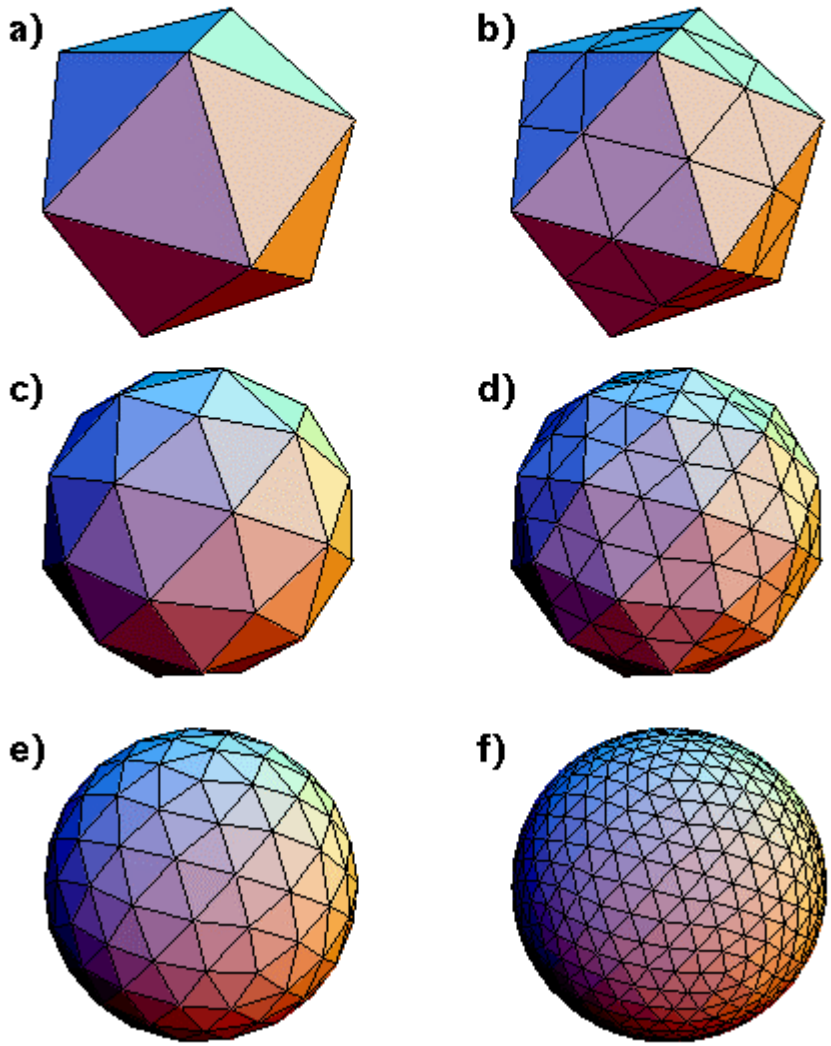
Octahedron: 1 base 8 digit plus unlimited base 4 digits

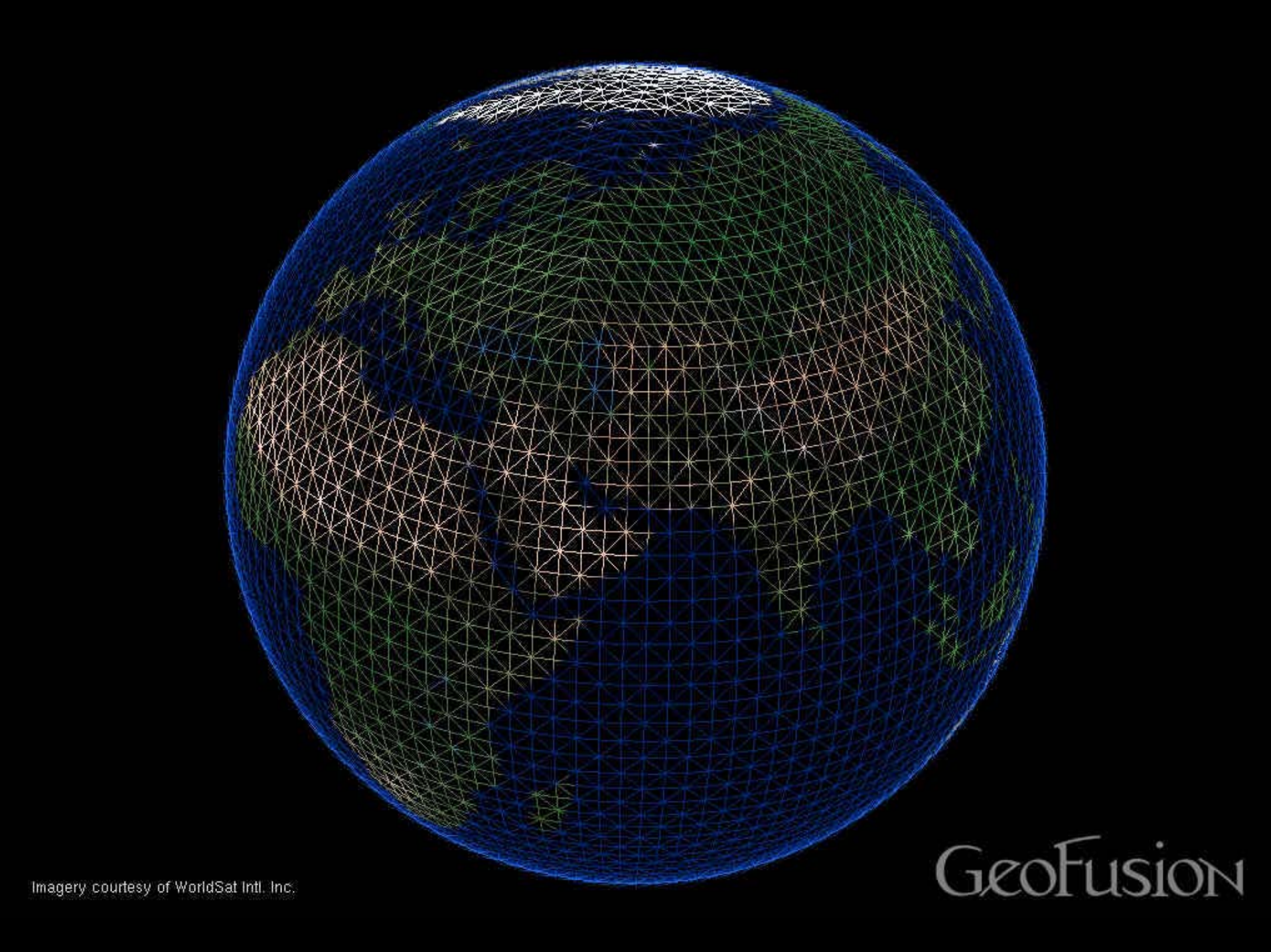
Discrete global grid based on the Icosahedron (20 triangles, 1:4 recursive subdivision)

Ross Heikes and David Randall, Colorado State University

Construction of a simple Icosahedral grid

a) Suppose we have an icosahedron inscribed inside of a unit sphere.
b) Bisecting each edge forms 30 new vertices, and partitions each equilateral face into four pieces.
c) Project the new vertices onto the unit sphere.
d) Bisect and partition again.
e) Project again.
f) And so on.... The result is a sequence of polyhedrons that increasingly approximate the sphere.




Imagery courtesy of WorldSat Intl. Inc.
GeoFusion

Imagery courtesy of WorldSat Intl. Inc.

GeoFusion

Concluding points

- Spatial perspectives are powerful
  - GIS and spatial analysis are now widely used in social science
  - several distinct purposes
  - two alternative world views
- Global perspectives are now feasible
  - supported by data integration tools
  - little experience with methods of analysis