

Welcome to GIS!

Michael F. Nelson

Intro to GIS – UMass Amherst – Michael F. Nelson

Today's agenda



Introductions and course structure



Syllabus key points



What is GIS?



Course Overview



Software



Big Concepts in GIS



GIS Applications

About The Course

The Basics

Introductions: About Me

- I'm a lecturer in the Department of Environmental Conservation
- Research and teaching interests include:
 - Invasion ecology
 - Spatial statistics, modeling, and GIS
- I learned GIS on my own, so you don't have to!
- Other courses I teach:
 - Intro to Quantitative Ecology
 - Analysis of Environmental Data
 - Spatial Data Analysis in R

Course Structure

- This is a hybrid synchronous/asynchronous course. It consists of lectures and optional lab sessions.
- Real-time lectures are held on Zoom Tuesdays and Thursdays 9:45AM – 11:00AM
 - Recordings of the lectures are posted to the course ECHO360 page.
 - Enrolled students will find links to the Zoom channel and the ECHO360 pages in Moodle (they are not public-facing).
- Labs are held Wednesdays 11:00 – 1:00 and Fridays 9:00 – 11:00

Synchronous Lecture Sessions

- These sessions will include:
 - Content delivery
 - Questions: Please feel free to interrupt me to ask questions at any time.
 - Map Puzzlers: these are meant to be fun exercises about mystery locations. Think Carmen Sandiego!
 - Map Showcase: This is your chance to show off the maps you create in lab!

Course Websites

GitHub

- Most course content is included here:
 - Lecture note pdfs
 - Lab instructions and data
 - Links to video walkthroughs and tutorials

Moodle

- There will be minimal content on Moodle. We'll primarily use it for:
 - Assignment submission
 - Midterm
 - Material that is for enrolled students only.
 - Non-public discussion forums

Lectures and Lecture Notes

- PDFs of the slides are posted to GitHub
- Slide PDFs will be updated as needed to account for questions that arise in class.
- Slide PDFs will be updated as needed to focus material on your interests.
- Slide PDFs will be updated as needed when errors are found!
- The most up-to-date slide PDFs can always be found on the course GitHub page.

Course Software

- GIS is software intensive... Lab 1 contains software instructions.
- Windows Virtual Desktop: this takes a couple of days to set up after your request.
 - Sign up for access [here](#) ASAP
- Expect to spend time troubleshooting! It's part of the joy of GIS.
 - Don't be afraid to ask for help when you get stuck (Dr. Google, me, your TA)
- Since this is a compressed summer schedule, you'll need to get started on software setup ASAP! Expect to have to do troubleshooting. The course software often runs smoothly, but if you run into problems, it's best to get them fixed early!

Lab Sessions and Office Hours



There are 2 optional lab sections per week.



I strongly encourage you to attend all or part of any lab session you can. They are great for questions, collaboration, and troubleshooting.



Office hours are held Thursdays after class 11:00AM – 1:00PM

Labs and Lab Due Dates

Labs are designed to:

1. Give you a chance to practice the concepts from lecture
2. Build your general and GIS problem solving skills
3. Build technical proficiency in Arc GIS software

Lab due dates are meant to keep your progress up to date and facilitate timely grading/feedback.

- Life happens. If you need more time, be in touch!
- You can find a list of assignment dates in the syllabus, or by examining the calendar feature in Moodle.
- Labs submitted after the due date will receive a 10% late penalty, unless we've made prior arrangements.

Midterm

- This exam is meant to:
 - Assess and reinforce your understanding of the lecture content.
 - Exercise your problem-solving skills.
 - Exercise and reinforce the technical skills you learned in labs 1 – 5
- The exam is open-book/open-notes, but...
- You may ask questions of your classmates; however, all questions should be posted in the publicly-accessible Midterm Forum on Moodle.
- We cannot answer technical questions on the midterm questions.

Final Projects and Posters

- You'll get a chance to apply your GIS knowledge and problem-skills to a real-life problem!
- We have a list of potential projects and data sources.
- You may select your own, custom project.
- This is a chance to be creative
- Poster session
- More info to come!

Syllabus Highlights

Full syllabus is on GitHub

- You are responsible for knowing the contents!

Important points:

- Ask us for help
- Don't get behind on labs
- Ask us for help

What can I expect of this course?

- What do you want to get out of it?
- How much effort will you put into it?

- Warning: you may feel overwhelmed at times, especially in the beginning. GIS isn't easy, but it is a lot of fun.

You Will be Overwhelmed
"Piled Higher and Deeper" (PhD) is the comic strip about life (or the lack thereof) in academia by Jorge Cham.

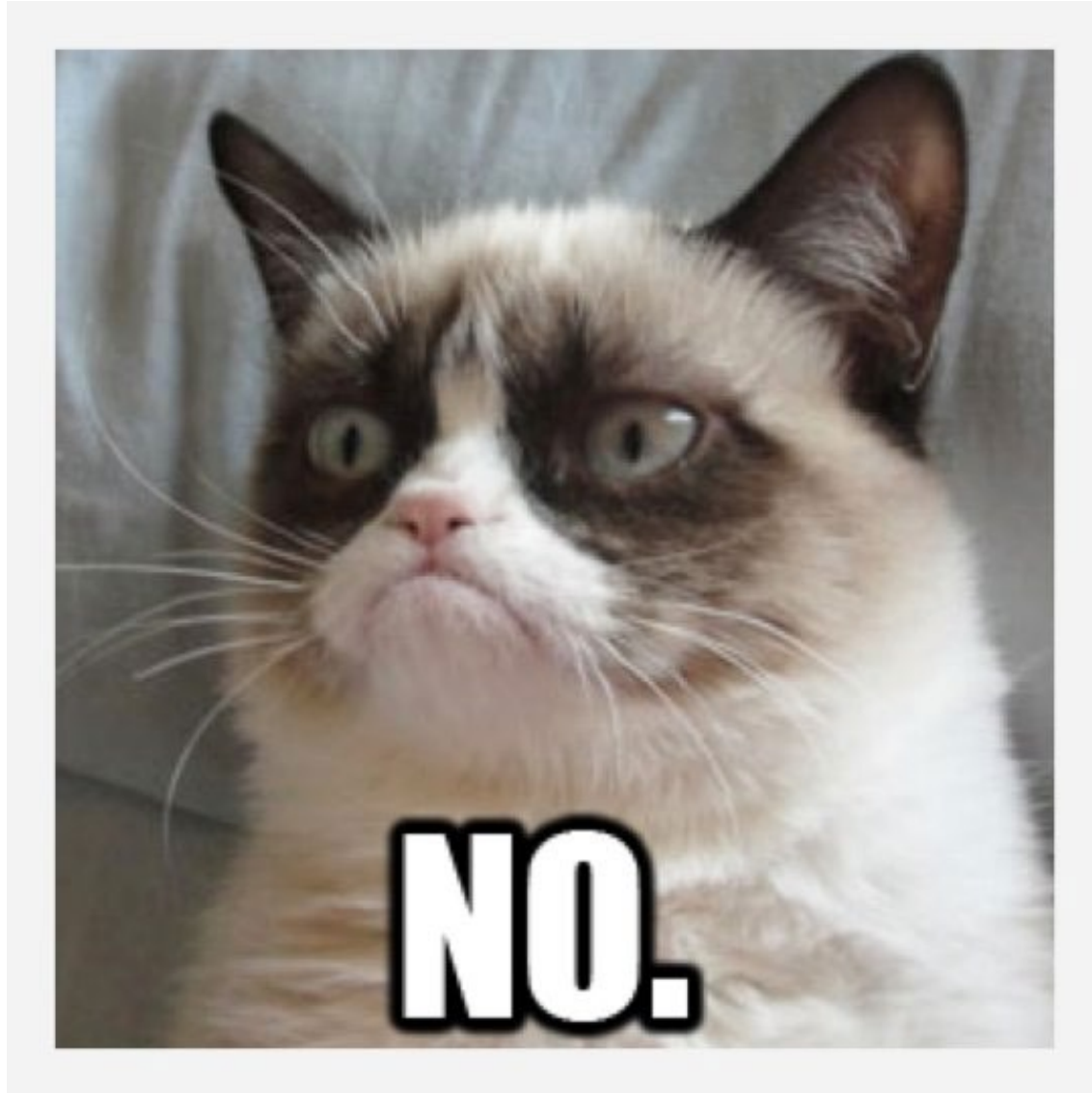


Intro GIS Myths and Misconceptions...



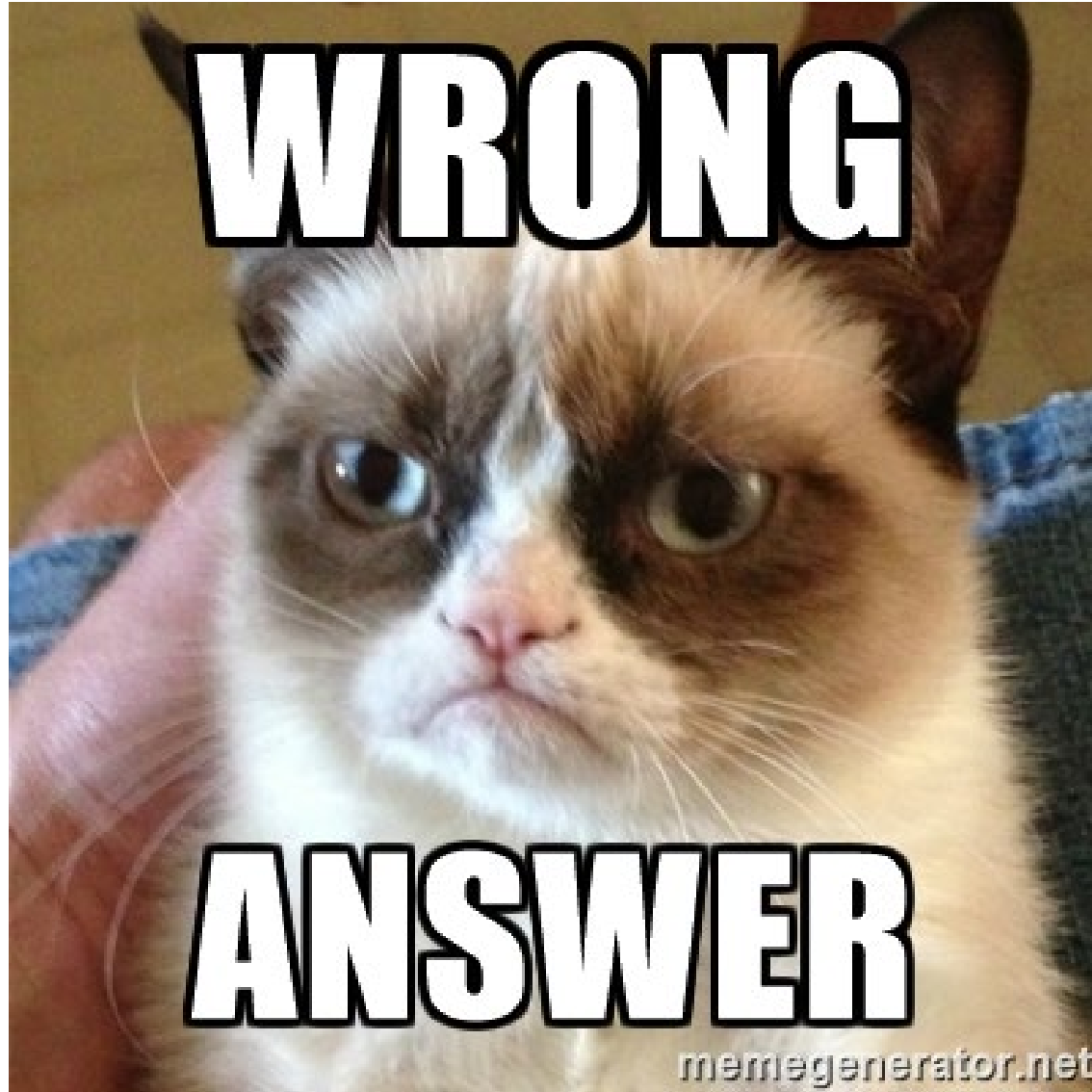
Intro to GIS Myths

MYTH: 'This course
is titled
'**Introduction** to
GIS', it's going to
be easy!"



Intro to GIS Myths

MYTH: 'We have
three hours in lab
each week, I'll
**never have to
work on GIS on my
own!**'



Intro to GIS
Myths

MYTH: 'This class
is just about
learning a
software package;
**I'll always be told
exactly what to
do'**



NOPE NOPE NOPE NOPE

Good news!



Even though this is not an easy course,
it *is* a lot of fun!



Software and concepts can be
challenging, but maps are awesome!

What you need to
succeed (with GIS)
Be organized!

It's likely that you'll
create a lot of similar
file names

You will not remember
anything about 'temp1'
the day after you
create it. Keep notes,
use intuitive file names.

Keep a log of useful
tools – ArcGIS naming
conventions are not
always intuitive

What you need to
succeed (with GIS)

Be organized!

Try not to get frustrated

Stress Reduction Kit



Directions:

1. Place kit on FIRM surface.
2. Follow directions in circle of kit.
3. Repeat step 2 as necessary, or until unconscious.
4. If unconscious, cease stress reduction activity.

What you need to succeed (with GIS)

Be organized!

Try not to get frustrated

Get started early

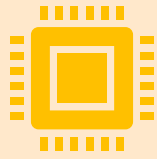
Save your work often

Use Google in addition to ArcGIS help

Ask someone if you can't solve it yourself



What you need to succeed (with GIS)



A moderately-sophisticated understanding of how your computer sees the world.



Resourcefulness, patience, creativity, and problem-solving skills.

Computers Poll!

Moderate Level of Computer Sophistication...



Don't worry if you didn't know all the terms in the Zoom poll.



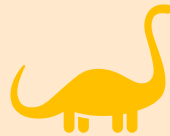
We will learn more about all of them during the course.

What is (a) GIS?

What is a GIS?



“A GIS is a computer-based system to aid in the collection, maintenance, storage, analysis, output, and distribution of spatial data”

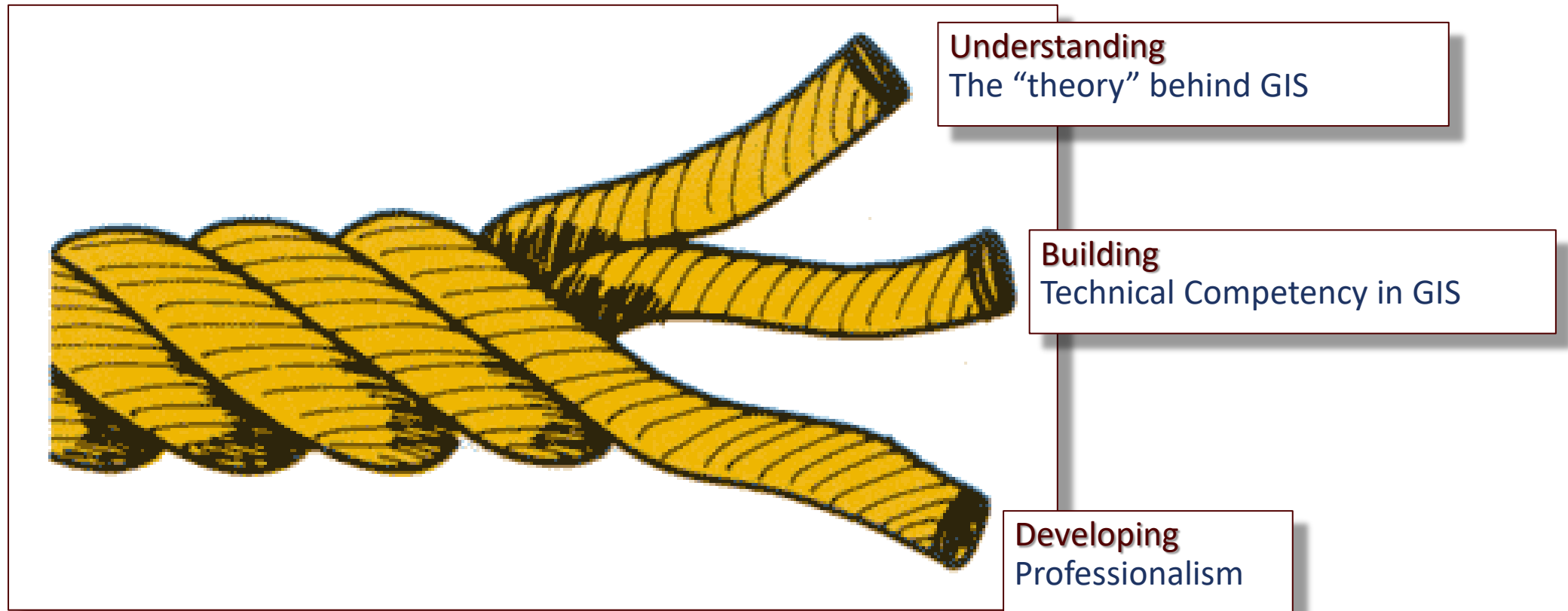


With GIS, we can ask (and answer) the question of ‘where’, not just ‘what’



People learn GIS for lots of reasons: academics, research, professional, agency work, and others!

Three Big Themes



Learning Objectives I

Geographic Information Science & Technology Body of Knowledge
Edited by David Edrington, Michael DeMaio, Ann Johnson, Karim Elmagrabi, Jane Fisher-Lewis, Bradenton Pflieger, and Elizabeth Wherry
UNIVERSITY CONSORTIUM FOR GEOGRAPHIC INFORMATION SCIENCE

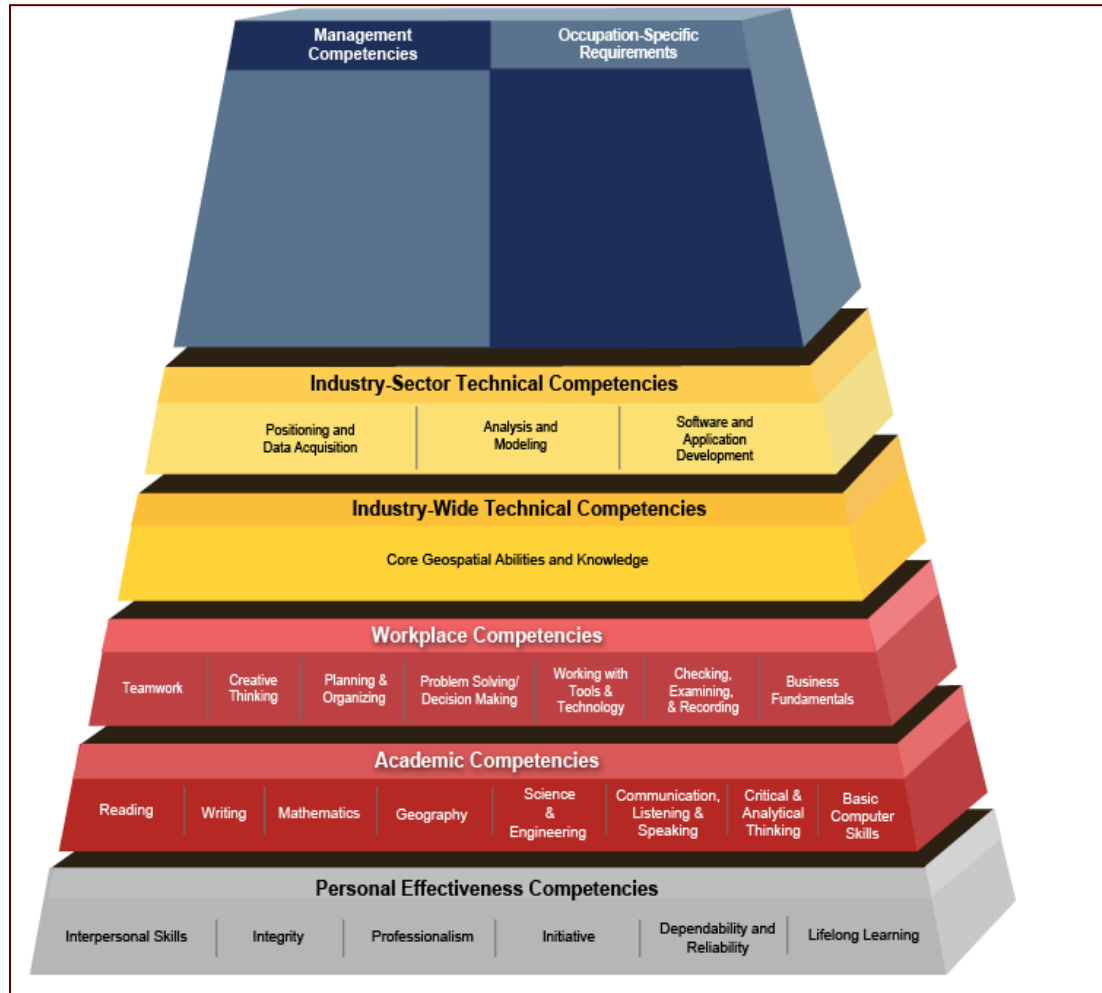
Analytical Methods <ul style="list-style-type: none">AM1 Academic and analytical origins<ul style="list-style-type: none">1.1 Academic foundations1.2 Foundational disciplinesAM2 Query operations and query languages<ul style="list-style-type: none">2.1 Query languages2.2 Database Query Languages (SQL) and spatial extensions2.3 Spatial queriesAM3 Geometric measures<ul style="list-style-type: none">3.1 Distance and length3.2 Area3.3 Volume3.4 Perimeter and distance decay3.5 Adjacency and connectivityAM4 Basic analytical operations<ul style="list-style-type: none">4.1 Buffering4.2 Clipping4.3 Intersections4.4 Map algebraAM5 Basic analytical methods<ul style="list-style-type: none">5.1 Point pattern analysis5.2 Density and density estimation5.3 Spatial cluster analysis5.4 Spatial interaction5.5 Mapping multi-dimensional attributes5.6 Cartographic modeling5.7 Multi-criteria evaluation5.8 Spatial process modelsAM6 Analysis of surfaces<ul style="list-style-type: none">6.1 Modeling surface phenomena6.2 Interpolation of surfaces6.3 Surface features6.4 Topography6.5 Profile surfaces	Cartography and Visualization <ul style="list-style-type: none">CV1 History and trends<ul style="list-style-type: none">1.1 History of cartography1.2 Modern cartographic practicesCV2 Data considerations<ul style="list-style-type: none">2.1 Data sources for mapping2.2 Data integration: vector, raster, and other geospatial data2.3 Data quality and cartographic accuracyCV3 Principles of map design<ul style="list-style-type: none">3.1 Map design objectives3.2 Cartographic communication3.3 User requirements and constraints3.4 Principles of cartographic and visualization designCV4 Graphic representation techniques<ul style="list-style-type: none">4.1 Point patterns mapping methods4.2 Line patterns mapping4.3 Symbols and interactive display4.4 Encoding methods4.5 Data mapping and visualization4.6 Pattern and interaction environments4.7 Specialization4.8 Visualization of temporal geographic data4.9 Visualization of uncertaintyCV5 Map production<ul style="list-style-type: none">5.1 Computer-assisted map production5.2 Map production5.3 Map distribution5.4 Evaluation and testing5.5 Impact of cartographyCV6 Map use and evaluation<ul style="list-style-type: none">6.1 The user of maps6.2 Map reading6.3 Map interpretation6.4 Evaluation and testing6.5 Impact of cartography
Conceptual Foundations <ul style="list-style-type: none">CF1 Philosophical foundations<ul style="list-style-type: none">1.1 Geography and cartography1.2 Epistemology1.3 Philosophical perspectivesCF2 Cognitive and social foundations<ul style="list-style-type: none">2.1 Theoretical foundations of geographic information science2.2 From concept to data2.3 Geography as a foundation for GIS2.4 Place and perception2.5 Perception and geographic information science2.6 Cultural influences2.7 Behavioral influencesCF3 Domains of geographic information<ul style="list-style-type: none">3.1 Time3.2 Space3.3 Knowledge structure: space and time3.4 IntegrationCF4 Elements of geographic information<ul style="list-style-type: none">4.1 Geographic entities4.2 Events and processes4.3 Patterns, rules and time4.4 Integrative modelsCF5 Relationships<ul style="list-style-type: none">5.1 Categories5.2 Hierarchical, associative relationships5.3 Geographical relationships: things, objects, places5.4 Topological relationships5.5 Directional relationships: distance and direction5.6 Spatial distribution5.7 Scale5.8 System integrationCF6 Imperfections in geographic information<ul style="list-style-type: none">6.1 Uncertainty6.2 Information models of ignorance: fuzzy sets and rough sets6.3 Dimensional uncertainty6.4 Mathematical models of uncertainty: probability and statistics	Design Aspects <ul style="list-style-type: none">DA1 The scope of GIS/IT systems design<ul style="list-style-type: none">1.1 Design objectives: represent, inform, and process1.2 Requirements of business, user, academic, and research1.3 The scope of GIS/IT applications1.4 The scope of GIS/IT design1.5 The scope of GIS/IT designDA2 Project definition<ul style="list-style-type: none">2.1 Planning for design2.2 Application/requirement selection2.3 Requirements analysis2.4 Data products, data content, data flowDA3 Resource planning<ul style="list-style-type: none">3.1 Feasibility analysis3.2 Software systems3.3 Data quality3.4 Labor and management3.5 Spatial facilities and equipment3.6 PricingDA4 Database design<ul style="list-style-type: none">4.1 Modeling needs4.2 Conceptual models4.3 Logical models4.4 Physical modelsDA5 Analysis design<ul style="list-style-type: none">5.1 Analyzing user/analyst requirements5.2 Modeling user/analyst requirements5.3 Modeling user/analyst requirements: GIS/IT5.4 Prototyping a production designDA6 Application design<ul style="list-style-type: none">6.1 Modular application design6.2 User interface6.3 Development environments for geographic applications6.4 Computer-aided software engineering (CASE) toolsDA7 System implementation<ul style="list-style-type: none">7.1 System testing7.2 Deployment plans7.3 System testing7.4 System support
Data Modeling <ul style="list-style-type: none">DM1 Basic storage and retrieval structures<ul style="list-style-type: none">1.1 Data file structures1.2 Data retrieval strategies1.3 Data compressionDM2 Database management systems<ul style="list-style-type: none">2.1 The evolution of DBMS systems2.2 Database architecture2.3 Database design2.4 Reliability of the relational modelDM3 Terrestrial data models<ul style="list-style-type: none">3.1 Geographical information systems3.2 Vector data models3.3 Raster data models3.4 The geospatial model3.5 The geospatial model: network, GIS, and GIS3.6 Geospatial data modelsDM4 Vector and object data models<ul style="list-style-type: none">4.1 Geospatial information systems4.2 Vector data models4.3 Object data models4.4 The geospatial model4.5 Geospatial data modelsDM5 Modeling 3D, uncertainty, and temporal phenomena<ul style="list-style-type: none">5.1 Geospatial information systems5.2 Modeling uncertainty5.3 Modeling time-dependent information	

The course is aligned with the Learning Objectives set forth in the

Geographic Information Science & Technology Body of Knowledge

Which “specifies what aspiring geospatial professionals need to know and be able to do.”

Learning Objectives II



This course will help provide you with some of the core competencies expected of a Geospatial Professional as specified in the

Geospatial Technology Competency Model (GTCM)

- We'll just scratch the surface
- I encourage you to check out the GTCM on your own

What is GI Science?

It's complicated...

But we're going to learn!

- GI Science blends concepts from many other disciplines. It includes elements of:
 - information science, 'big data', and computer science
 - Geography and cartography
 - Ecology, conservation, and policy
 - Probability and statistics
 - And others

Communicating with your Peers

- For now, I will set up Moodle Forums.
- I encourage students to self-organize into groups to collaborate on labs.
- I also encourage students to communicate outside of class, or in forums that your instructor isn't part of. It's helpful to have a space where you can express your ideas without your instructor present!
 - I'll leave it up to you to decide what format this may take.
 - Slack? Discord?

Semester Overview

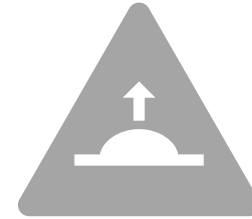
Semester in Twenty Minutes (ish)



A run through of our semester ahead.



Focus on big topics and important dates.



Should feel overwhelming (it is!)

Semester in Twenty Minutes (ish)



Software

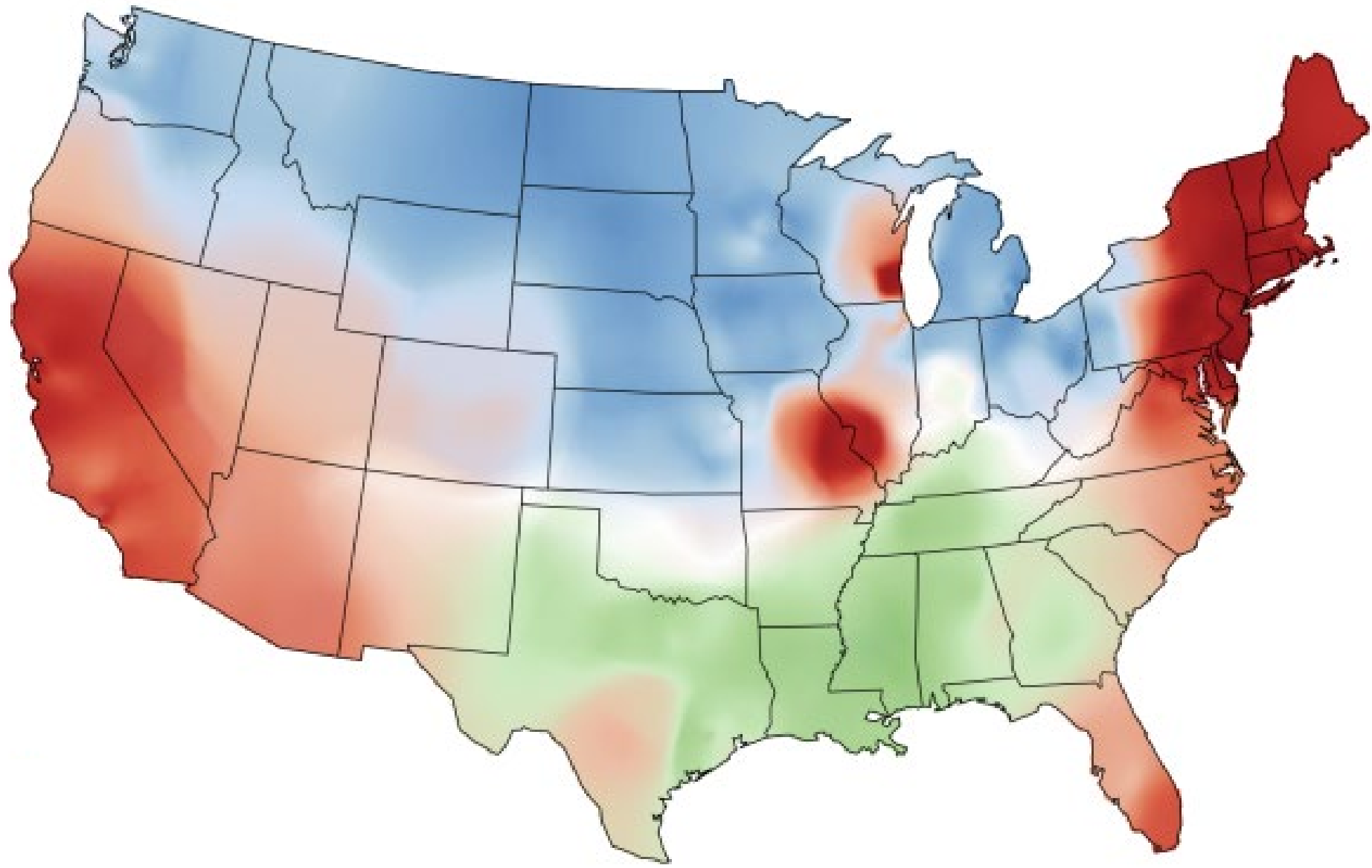


Big concepts

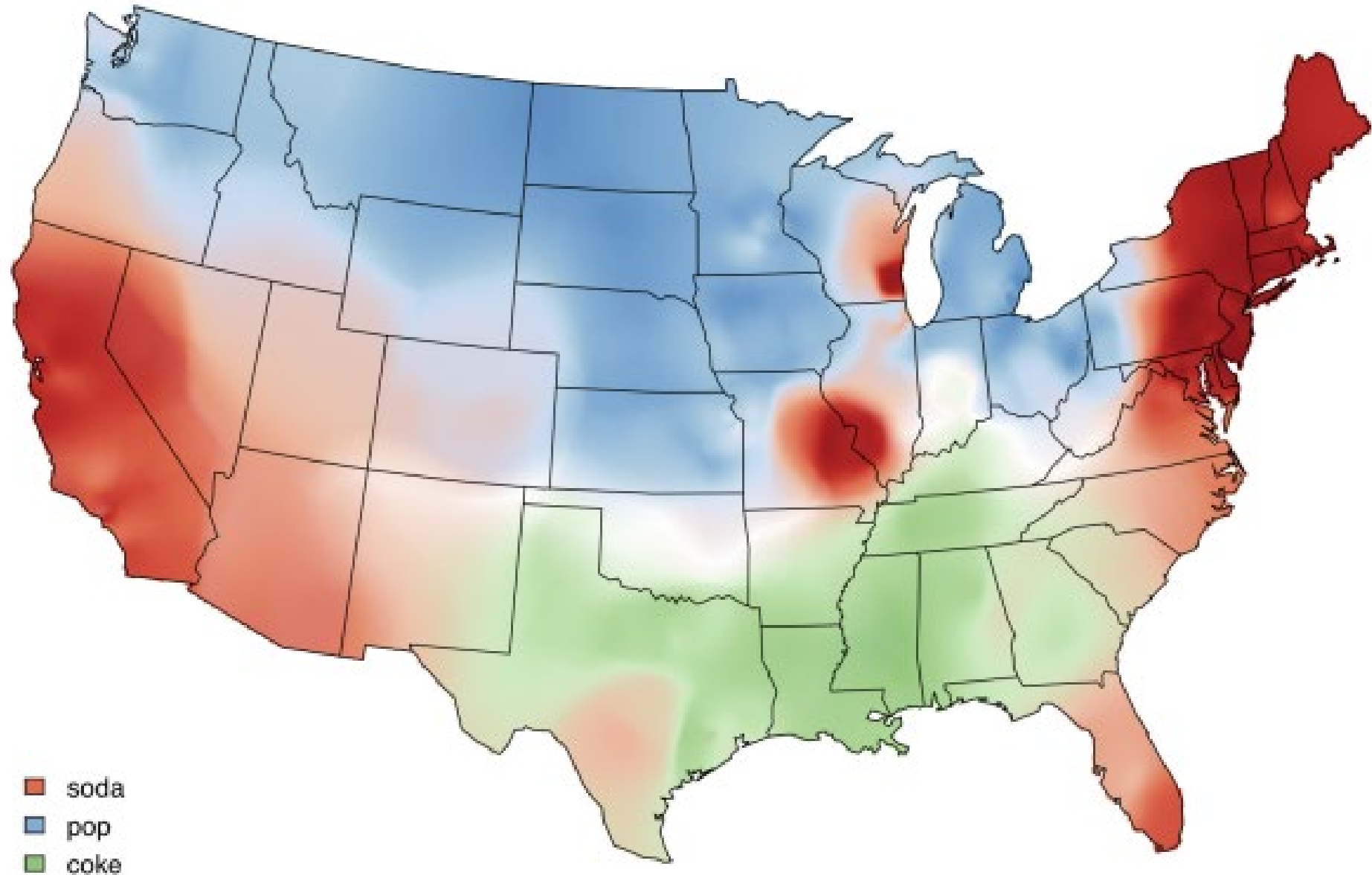


Labs

But first... A map puzzler!



What is your generic term for a sweetened, carbonated beverage?



Map by Joshua Katz, Department of Statistics, NC State University
Based on survey data from Bert Vaux, Department of Linguistics, University of Cambridge

GIS is not just ESRI

Concepts vs implementation!

GIS Software

GIS Software

GRASS GIS

Qgis

R

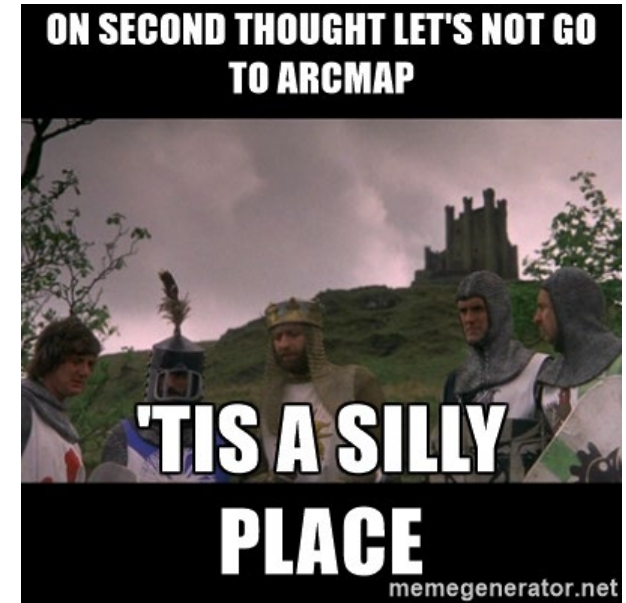
Python

Lots of niche tools

The ESRI universe

- **We'll use ArcGIS Pro**

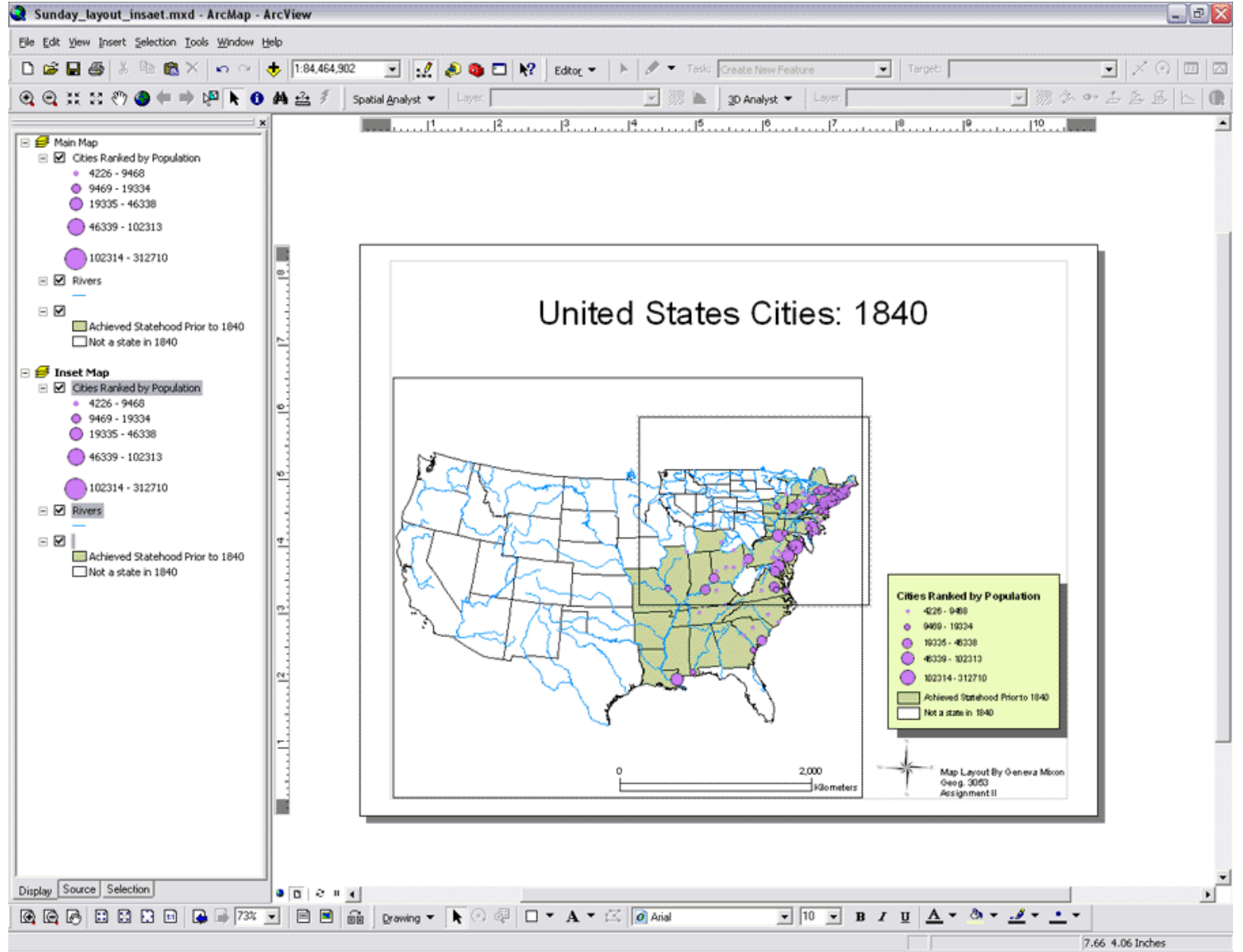
We'll be using ArcGIS Pro



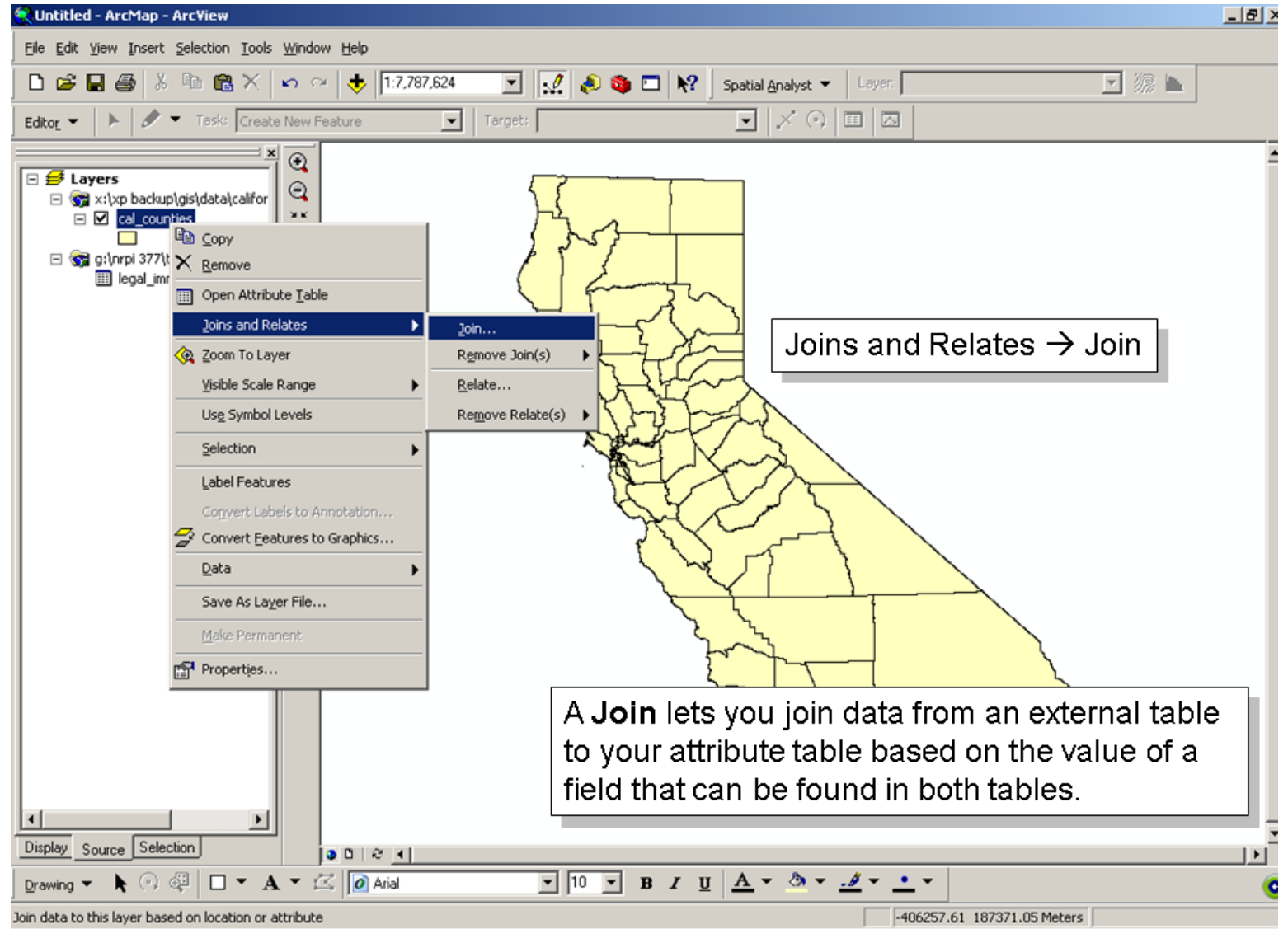
Arc History

- The current iteration of the main ESRI software is called ArcGIS Pro.
- Pro is meant to replace the earlier ArcGIS Desktop. The component most people are familiar with is ArcMap.
- Lots of people still use ArcMap – You'll find lots of help online for both Desktop and Pro. Unfortunately, ArcMap help entries are usually not directly applicable to Pro.
- ESRI software runs on Windows only 😞
 - Don't despair – we have workarounds for you.

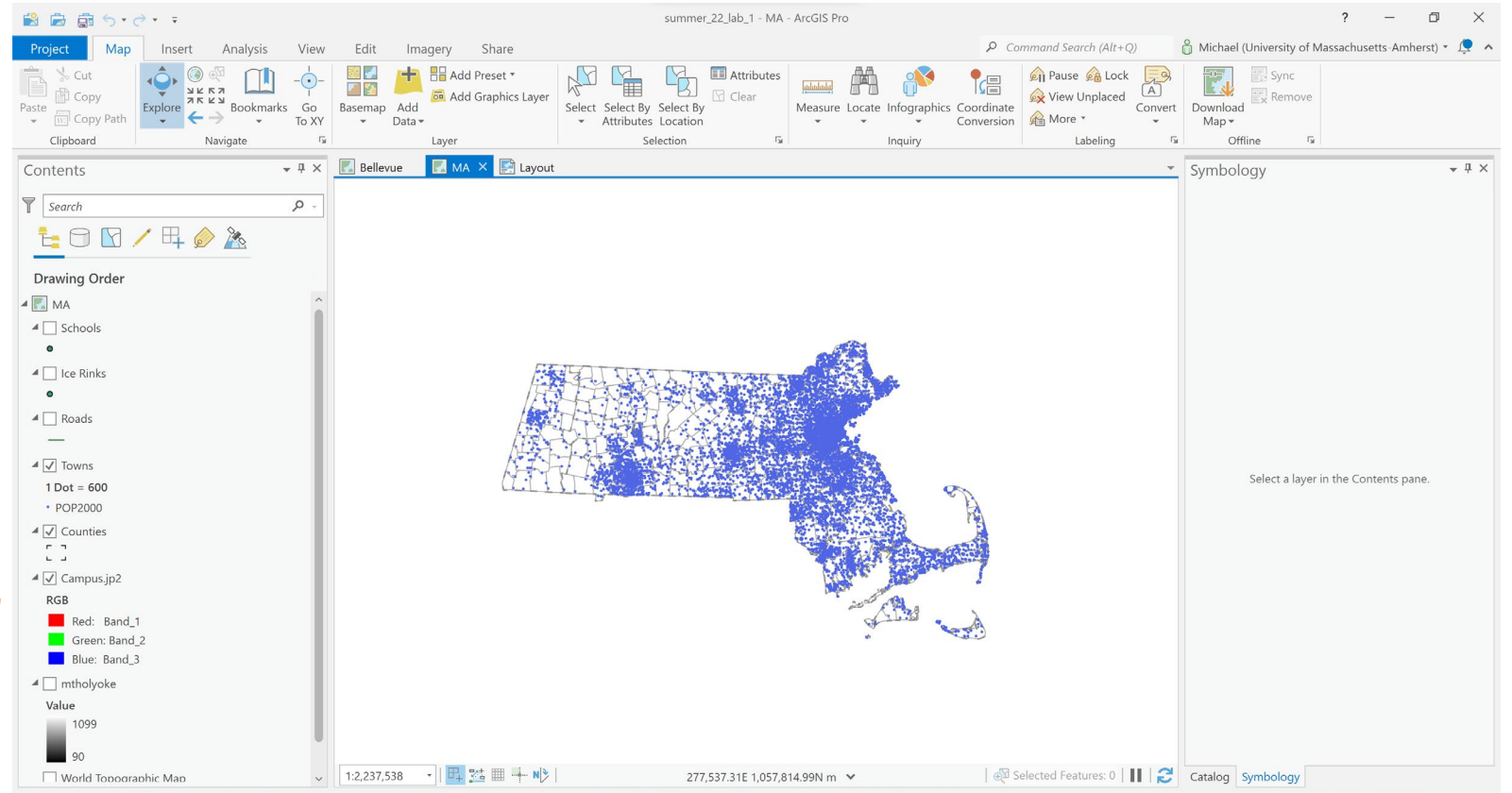
ArcMap



ArcMap



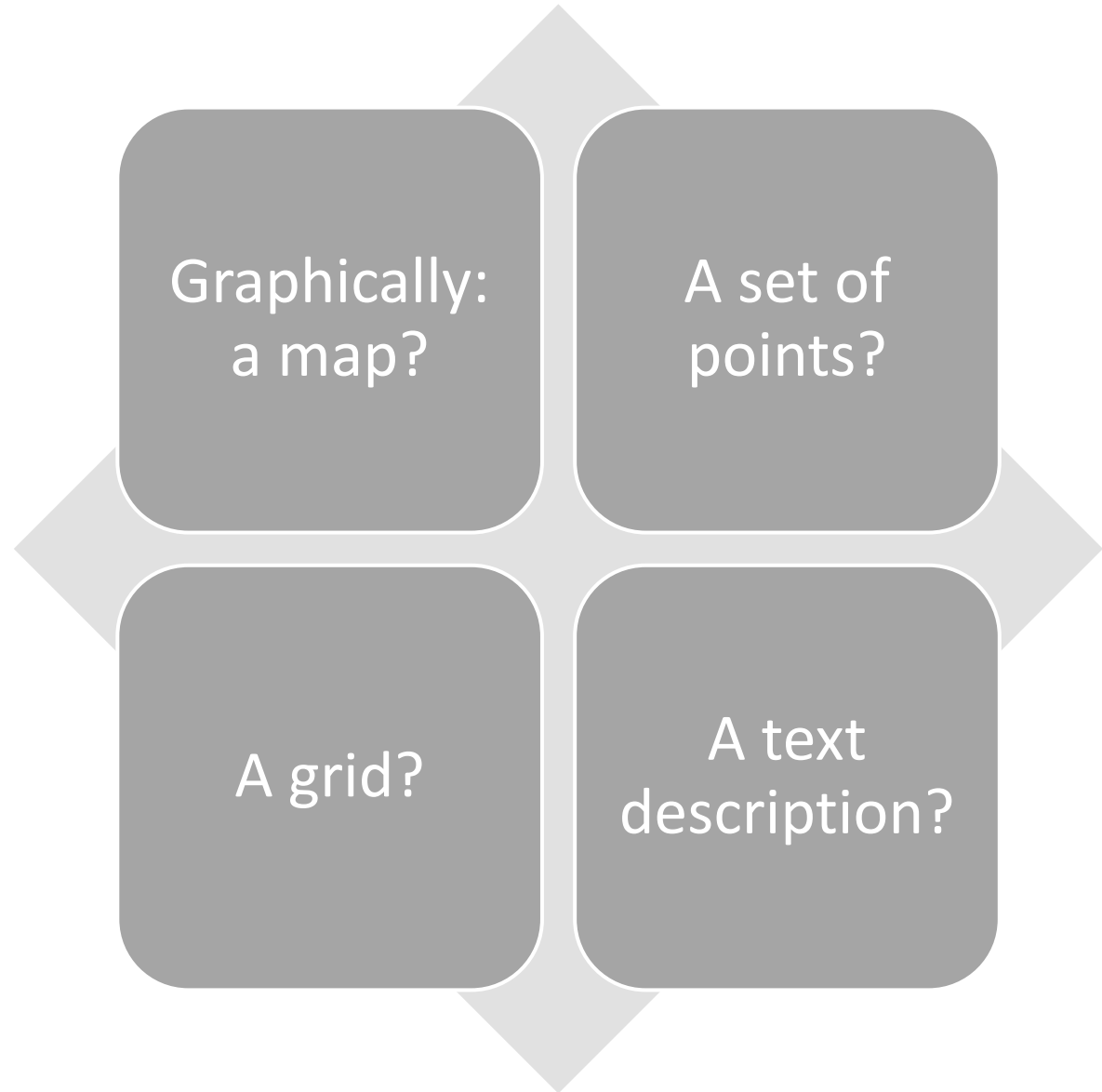
Arc Pro



Big Concepts in GIS

Spatial Data Representation

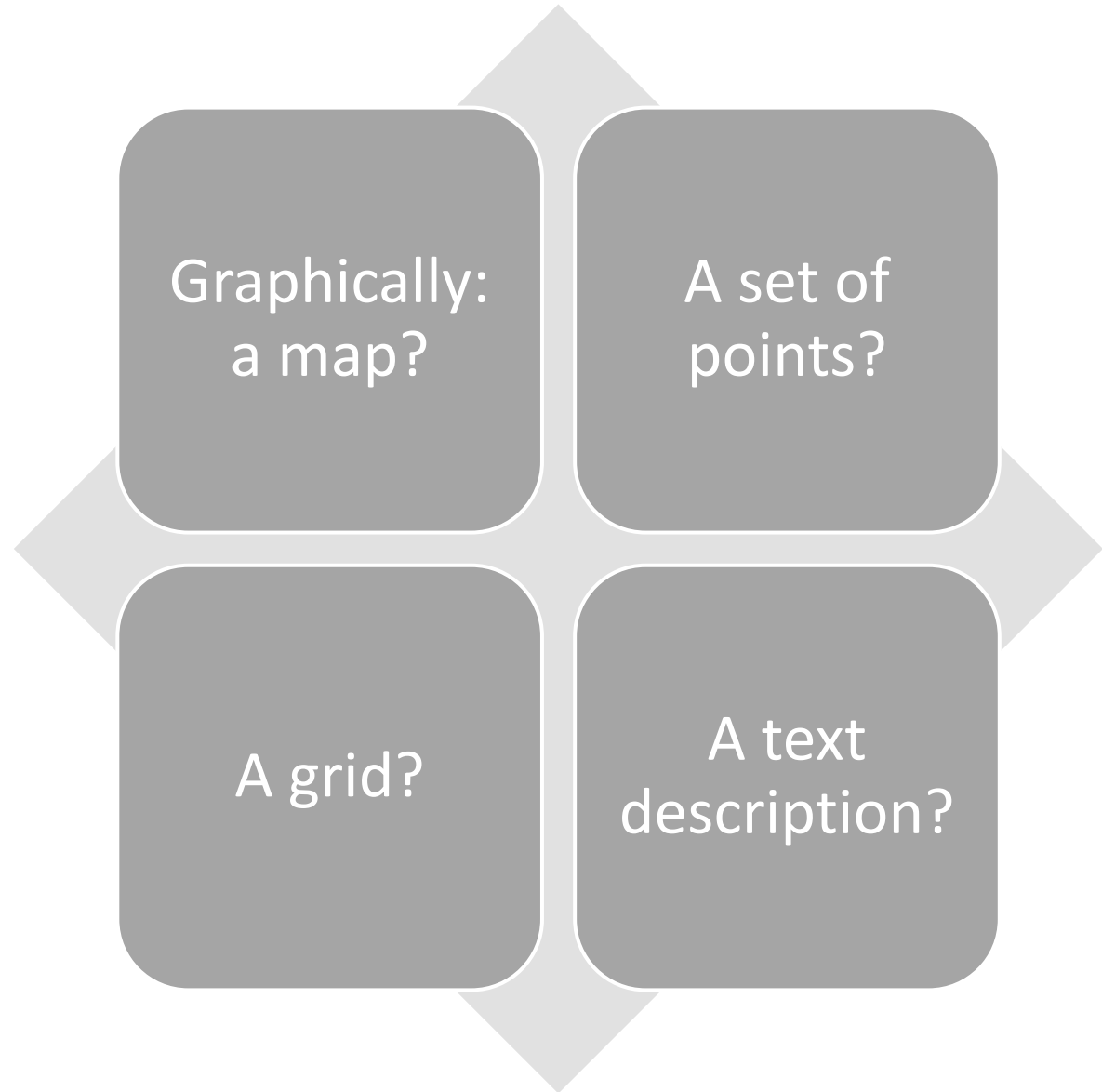
What's the best way to represent space?



It's time for a poll: Spatial Data!



Each of these
are valid
models of
spatial
phenomena!



How we
represent
spatial data
depends
on:

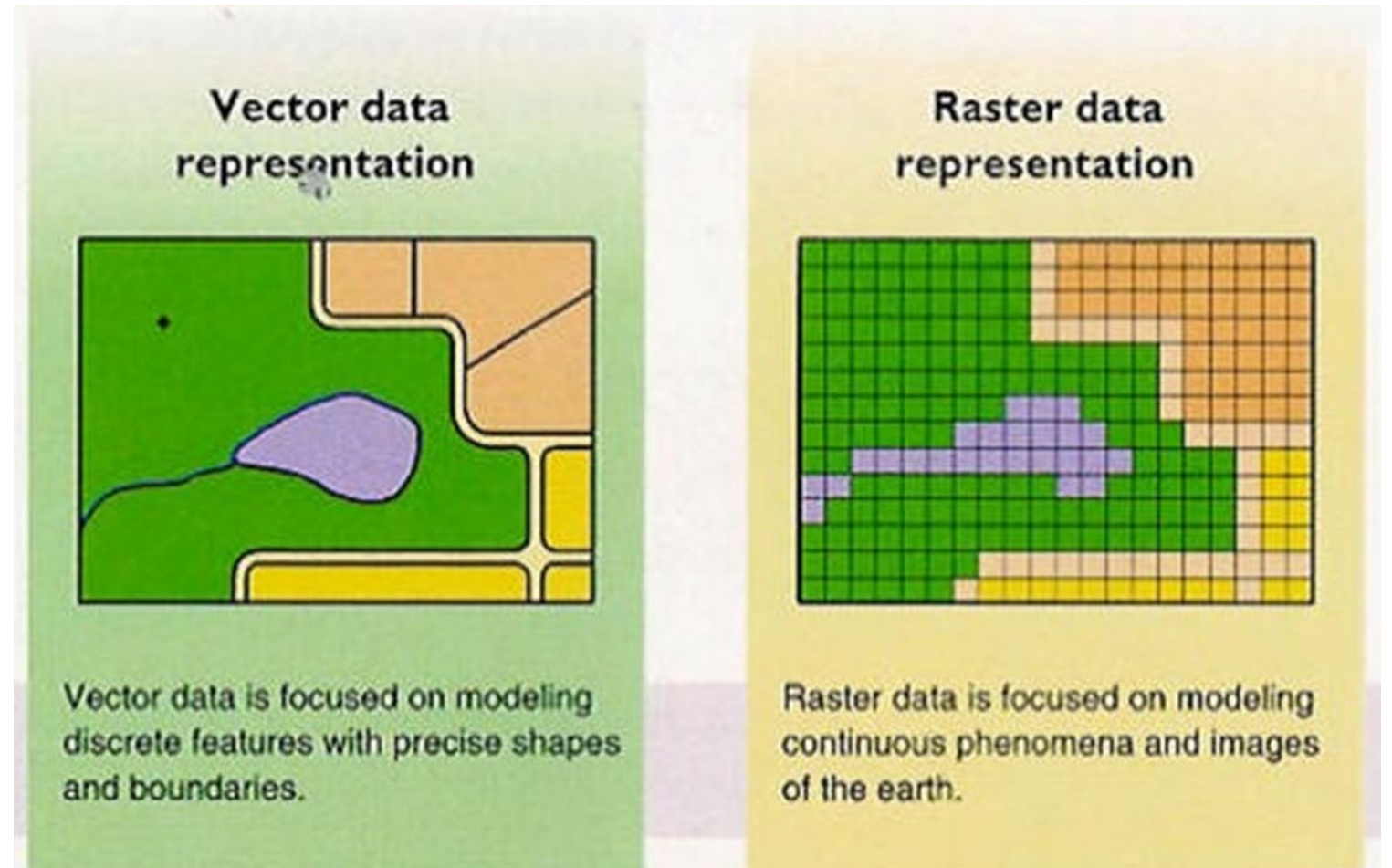


The nature of the spatial entity: is it a mountain? A tree? A river?



Our focus: do we care about shapes? Relative positions? Distances?

We'll learn
all about
vector and
raster data
models!



<http://map.sdsu.edu/geog104/lecture/unit-2.htm>

Big Concepts in GIS

Map Projections

Maps are flat,
but the Earth
is not!

What's the best
way to represent a
curved and lumpy
shape on a 2-
dimensional
surface?



Projections and Coordinate Systems



Oh, projections....

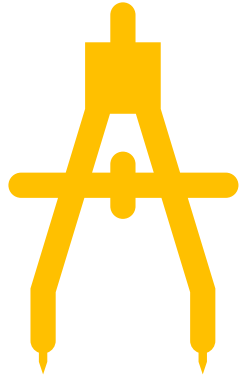


Which is bigger, USA or Brasil?

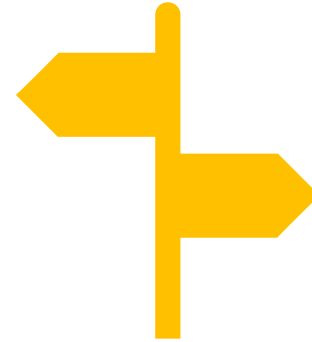


[Let's check out some areas.](#)

What is a projection?

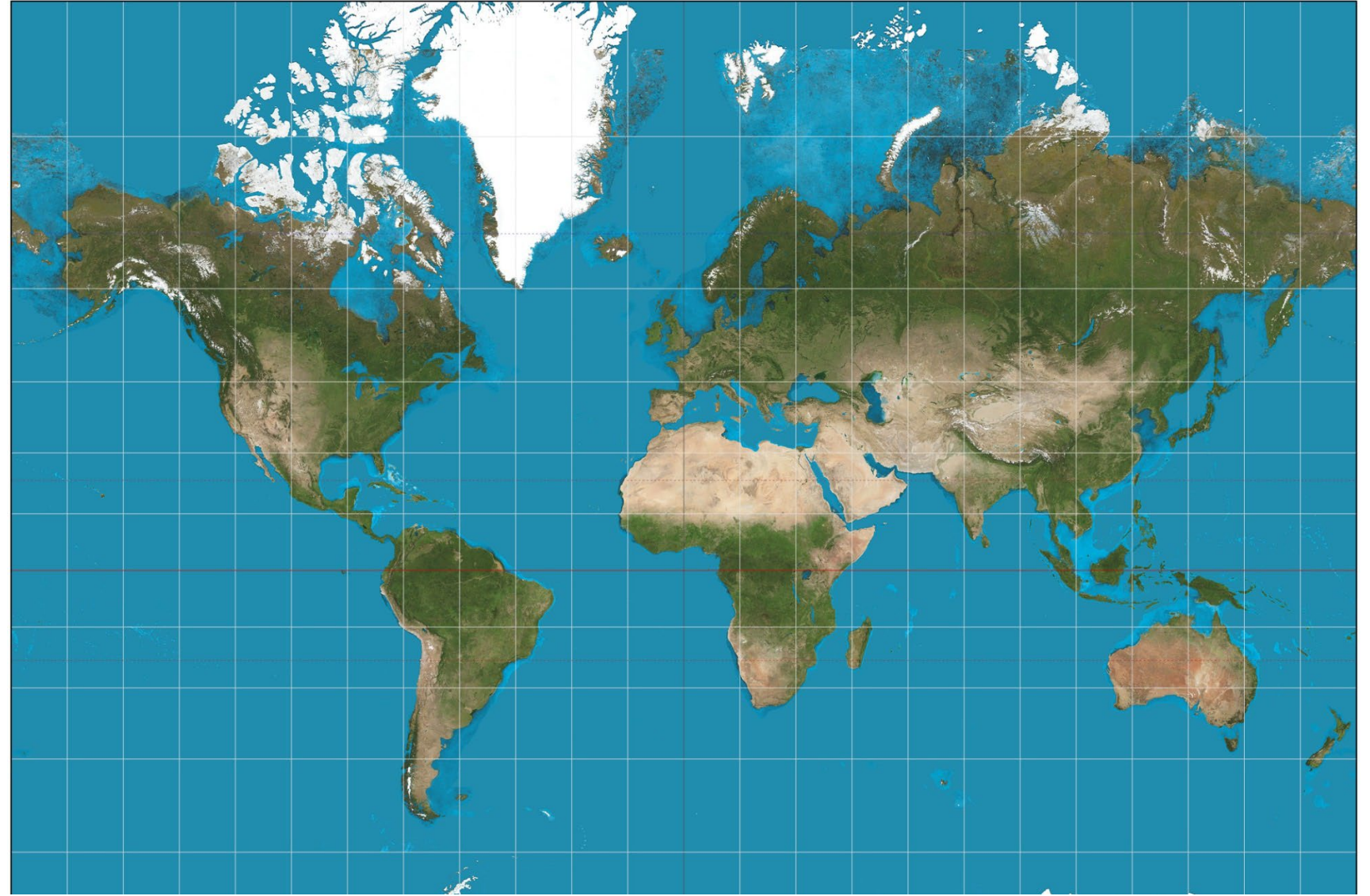


A projection is a mathematical transformation from a curved surface to a flat one.

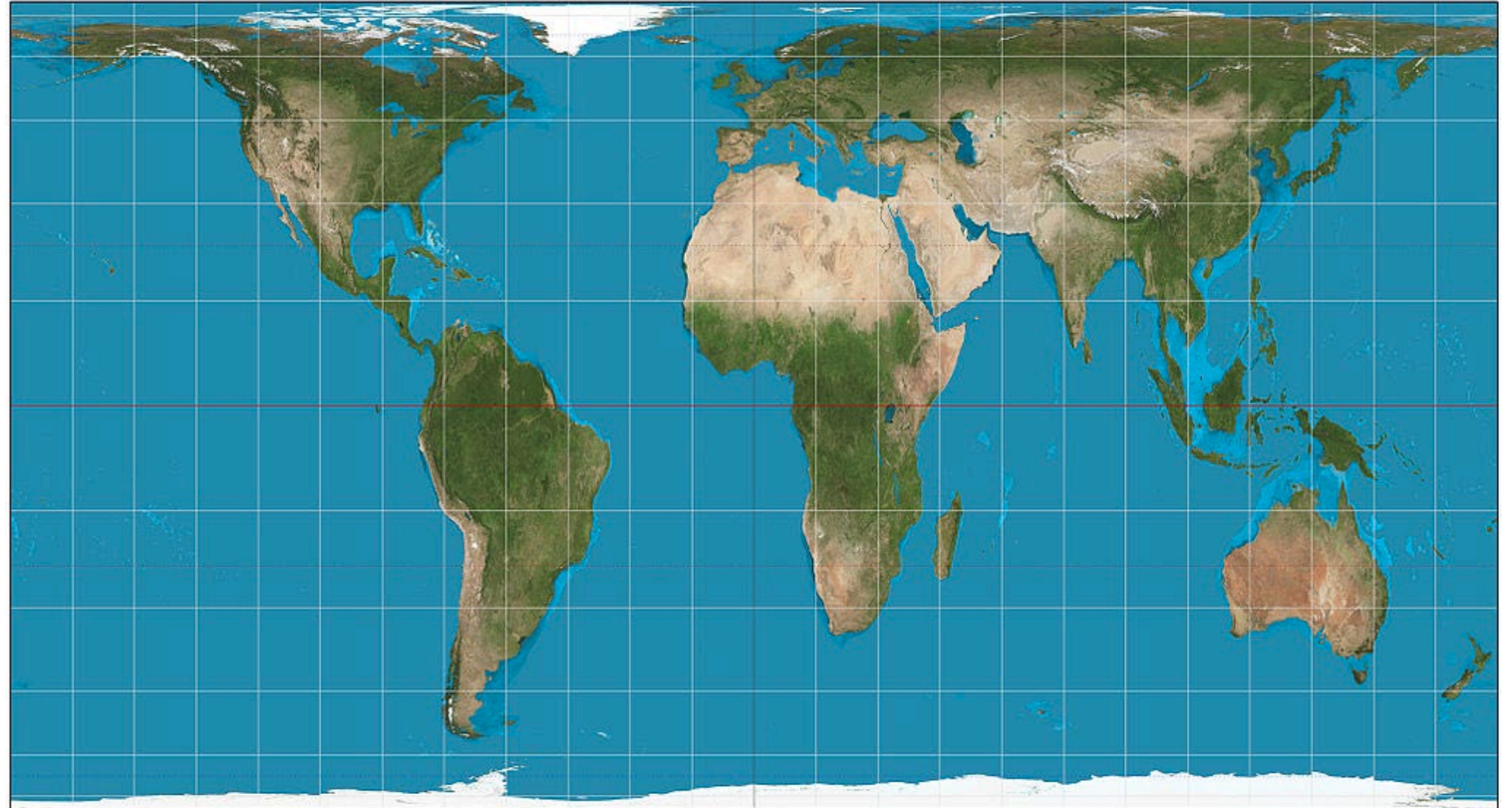


Projections are all about compromise.

World with Mercator Projection



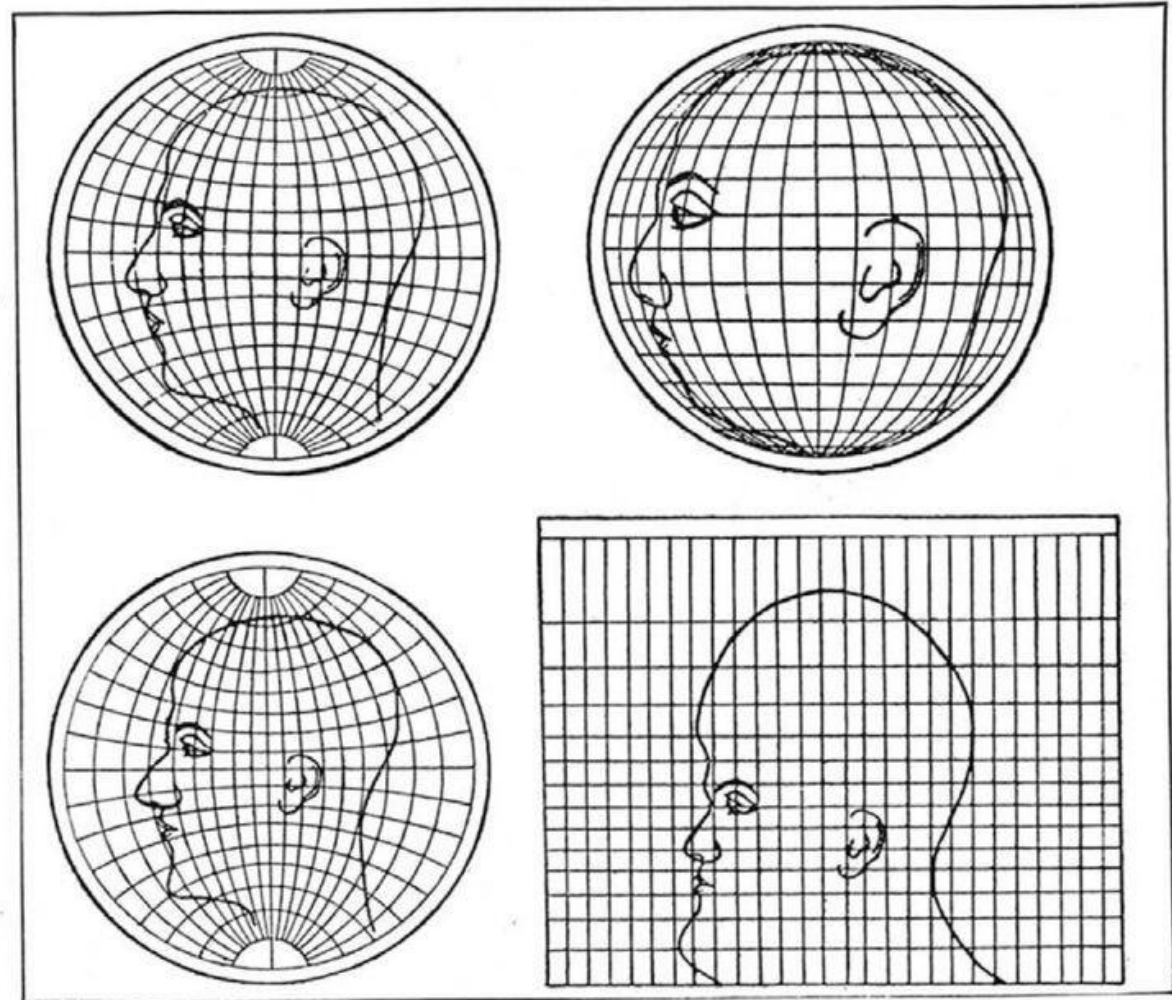
Equal Area
Projection – Is
this better?



Projections
make us think
about
representation



Projecting
always
introduces
distortion.



*Upper left: Globular. Upper right: Orthographic. Lower left: Stereographic.
Lower right: Mercator*

What four commonly used projections do, as shown on a human head

What is the shape of the Earth?

Hint: It's not a sphere!

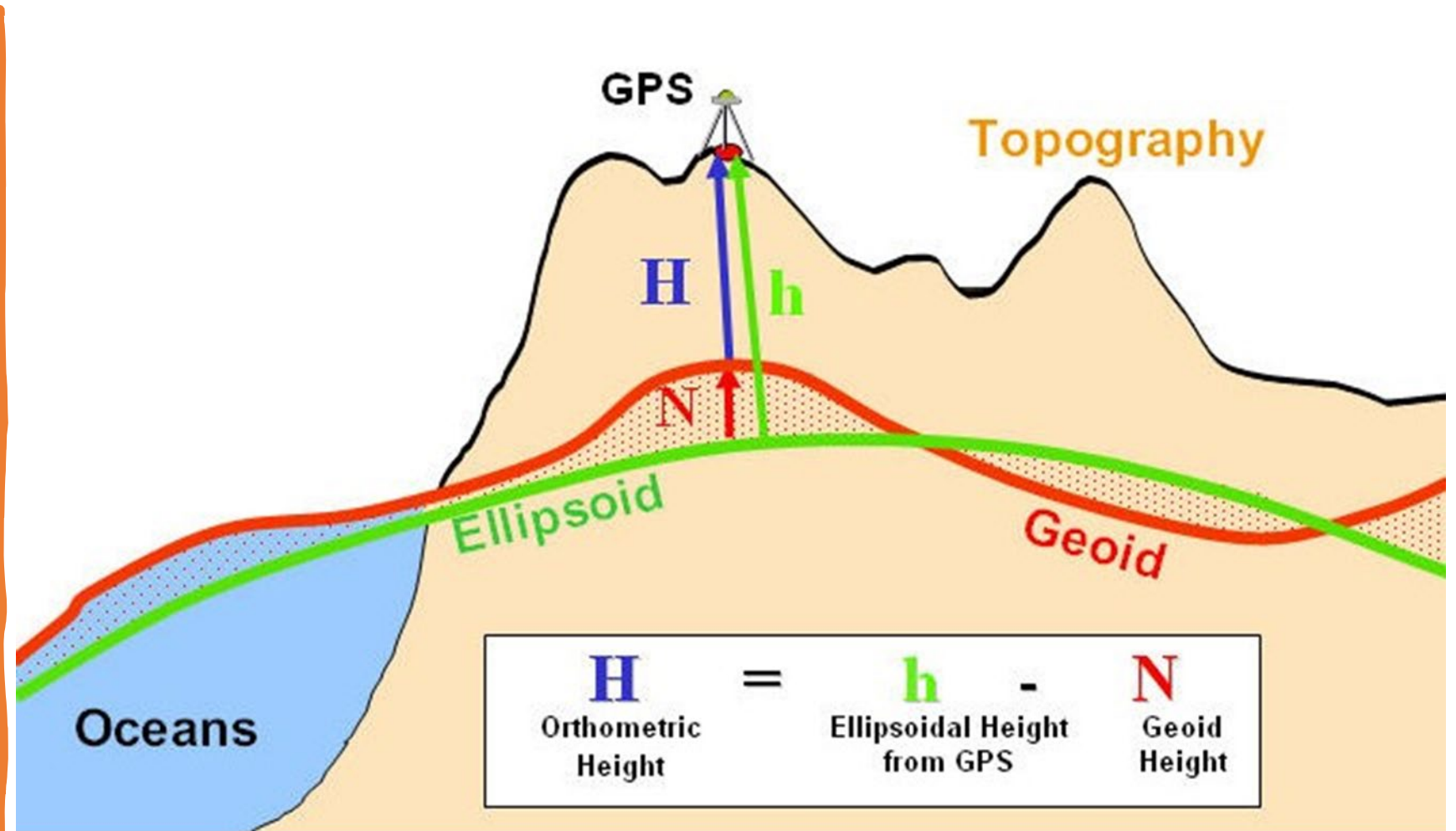


Image via University of Oklahoma at http://principles.ou.edu/earth_figure_gravity/geoid/

What is the right projection?

We'll save that question for
later...



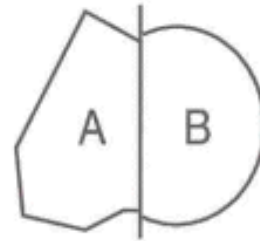
Big Concepts in GIS

Spatial Relationships and Operations

Arrangement of spatial features

TOPOLOGY SPATIAL RELATIONSHIPS

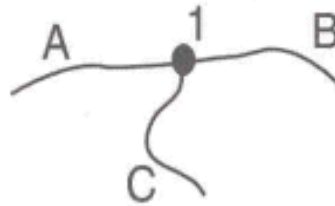
CHAIN 1



LEFT POLY = A

RIGHT POLY = B

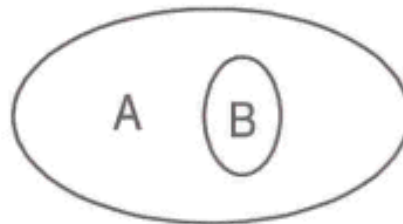
ADJACENCY



NODE 1 = CHAINS A, B, C

CHAIN A IS CONNECTED
TO CHAINS B and C

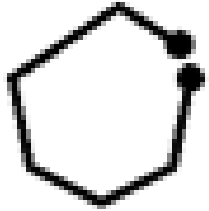
CONNECTIVITY



POLY B CONTAINED
WITHIN POLY A

CONTAINMENT

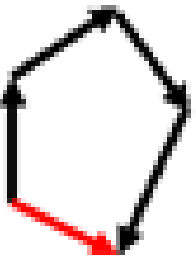
Polygon Construction and Editing



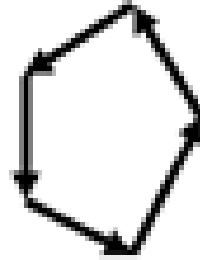
a. Polygon is not closed (start and end points do not overlap)



b. Polygon intersects itself (a 'bow-tie')



c. Segments forming polygon are not all oriented in the same direction

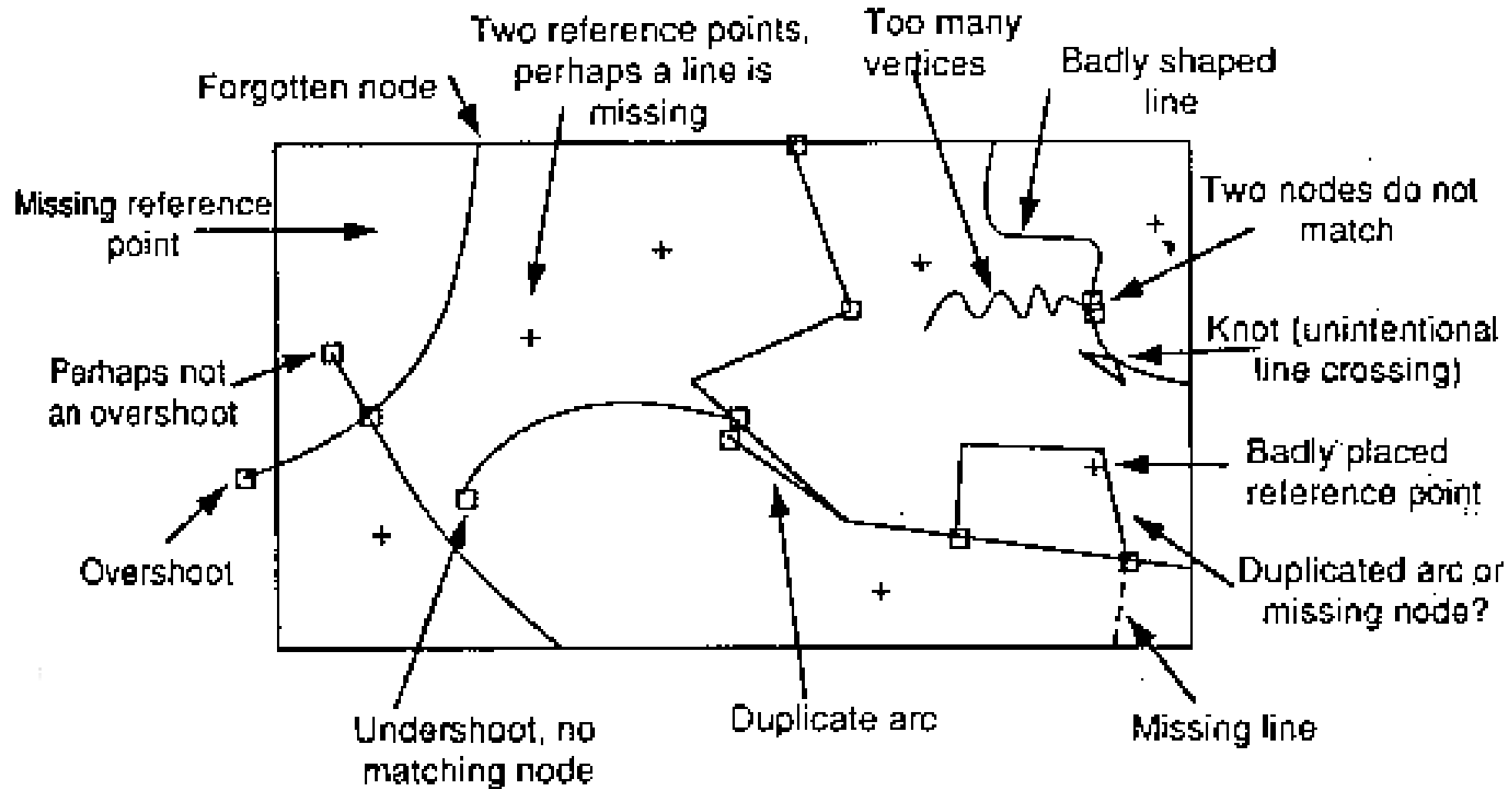


d. Polygon is oriented in anti-clockwise direction rather than clockwise



e. Polygon has a dangling segment (dead-end)

Spatial Data Troubleshooting

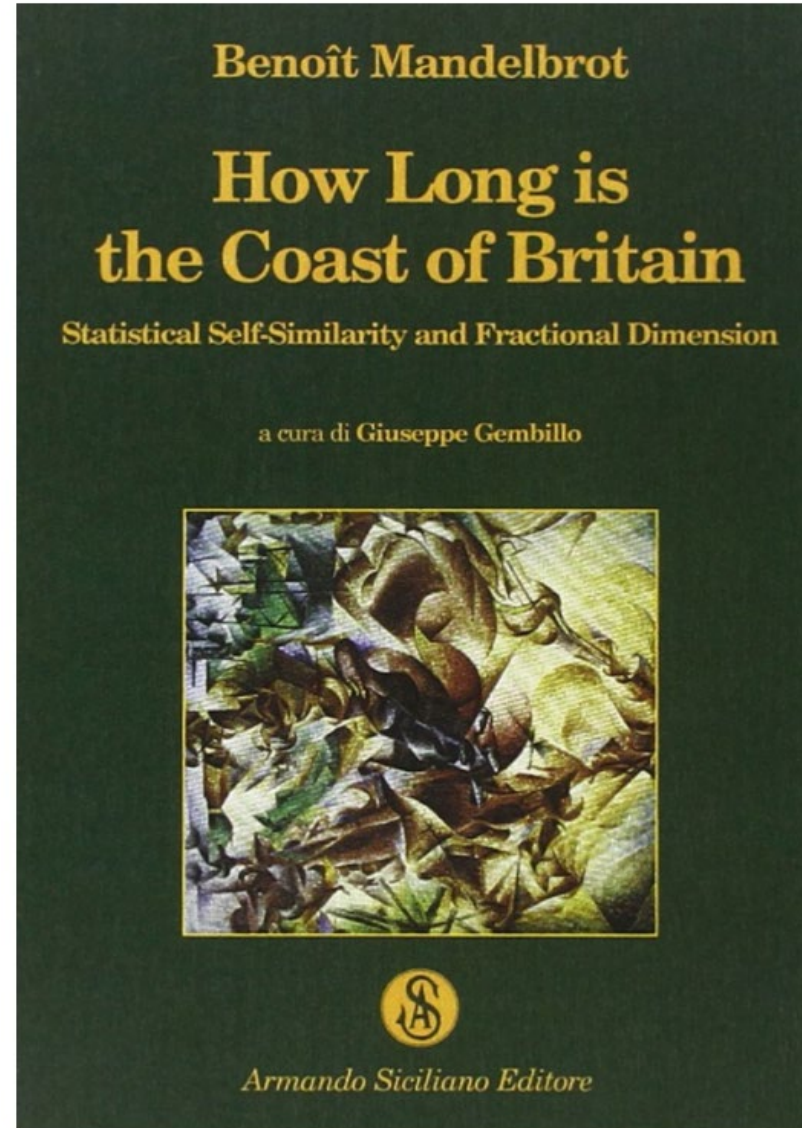


Logical Operations

TABLE 1-1 Basic Identities of Boolean Algebra

(1) $x + 0 = x$	(2) $x \cdot 0 = 0$
(3) $x + 1 = 1$	(4) $x \cdot 1 = x$
(5) $x + x = x$	(6) $x \cdot x = x$
(7) $x + x' = 1$	(8) $x \cdot x' = 0$
(9) $x + y = y + x$	(10) $xy = yx$
(11) $x + (y + z) = (x + y) + z$	(12) $x(yz) = (xy)z$
(13) $x(y + z) = xy + xz$	(14) $x + yx = (x + y)(x + z)$
(15) $(x + y)' = x'y'$	(16) $(xy)' = x' + y'$
(17) $(x')' = x$	

How do you
measure the
distance of a
complicated
curve?



Big Concepts in GIS

Probability and Statistics, Modeling, and Computational Thinking

Spatial Autocorrelation

An application of a statistical concept (correlation coefficient) to spatial phenomena

<http://pro.arcgis.com/en/pro-app/tool-reference/spatial-statistics/h-how-spatial-autocorrelation-moran-s-i-spatial-st.htm>

The Moran's I statistic for spatial autocorrelation is given as:

$$I = \frac{n \sum_{i=1}^n \sum_{j=1}^n w_{i,j} z_i z_j}{S_0 \sum_{i=1}^n z_i^2} \quad (1)$$

where z_i is the deviation of an attribute for feature i from its mean ($x_i - \bar{X}$), $w_{i,j}$ is the spatial weight between feature i and j , n is equal to the total number of features, and S_0 is the aggregate of all the spatial weights:

$$S_0 = \sum_{i=1}^n \sum_{j=1}^n w_{i,j} \quad (2)$$

The z_I -score for the statistic is computed as:

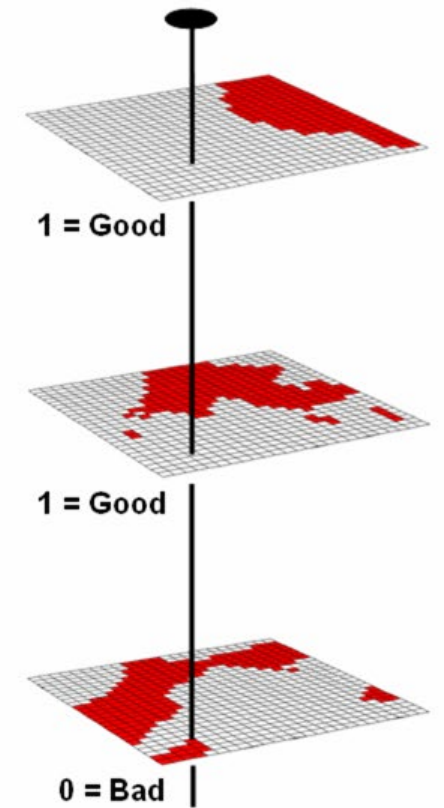
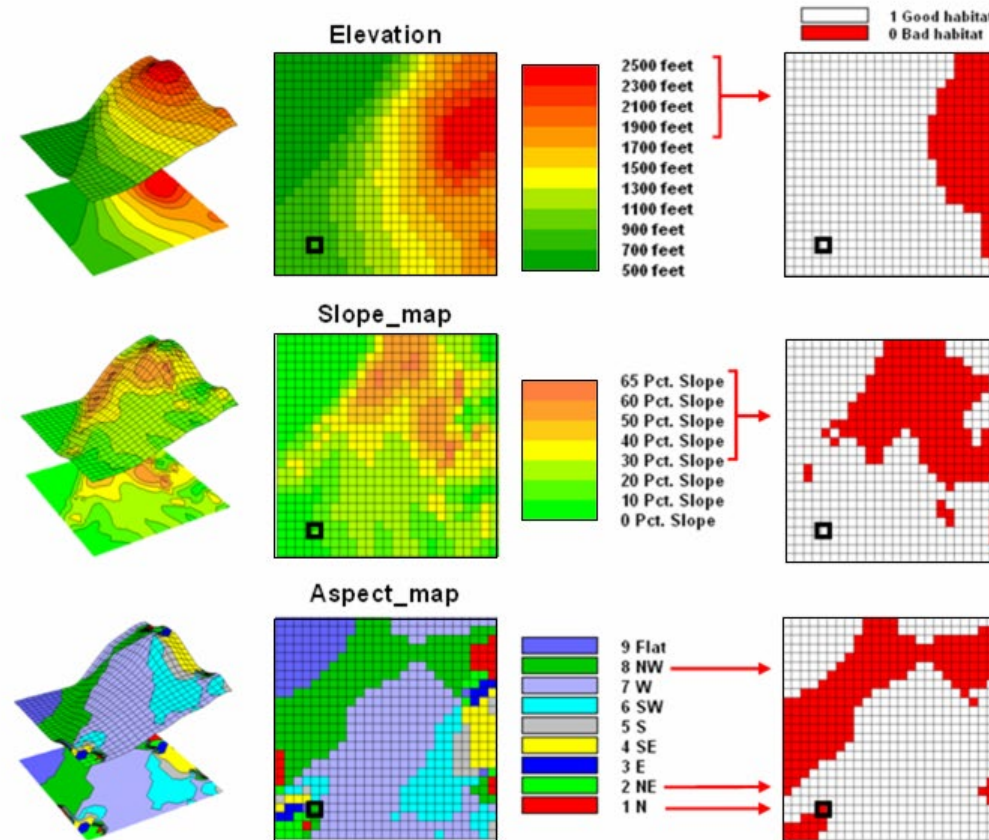
$$z_I = \frac{I - E[I]}{\sqrt{V[I]}} \quad (3)$$

where:

$$E[I] = -1/(n - 1) \quad (4)$$

$$V[I] = E[I^2] - E[I]^2 \quad (5)$$

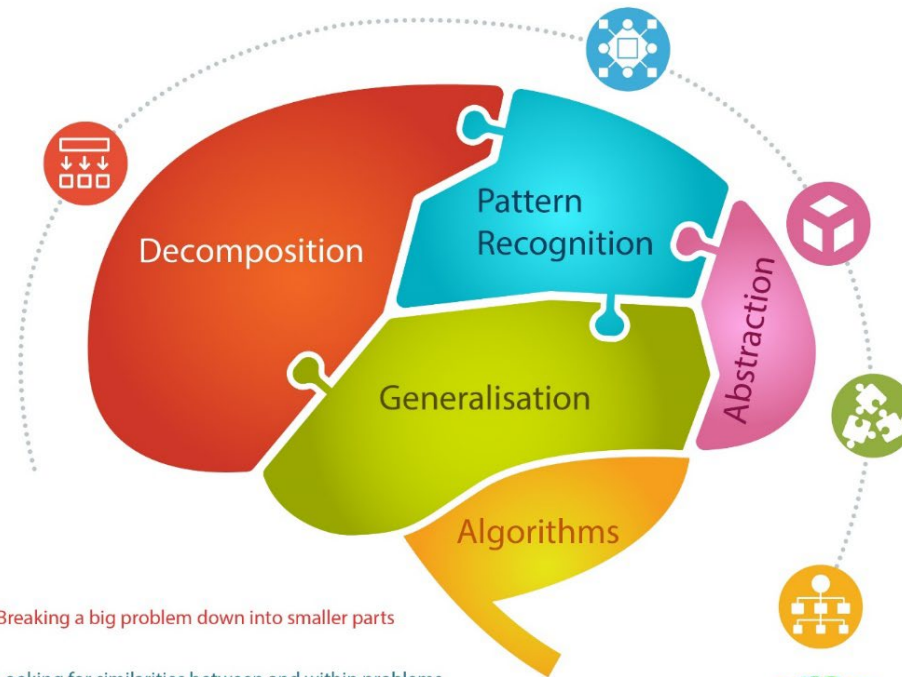
How do we model terrain?
What can we use our model for?










Computational Thinking

Computational Thinking is Model Thinking



-  Breaking a big problem down into smaller parts
-  Looking for similarities between and within problems
-  Taking the detail out of a problem and ignoring irrelevant information
-  Adapting solutions to other problems to solve new ones
-  Simple rules to follow that solve the problem



A GIS modeling process

Geographic Inquiry Process

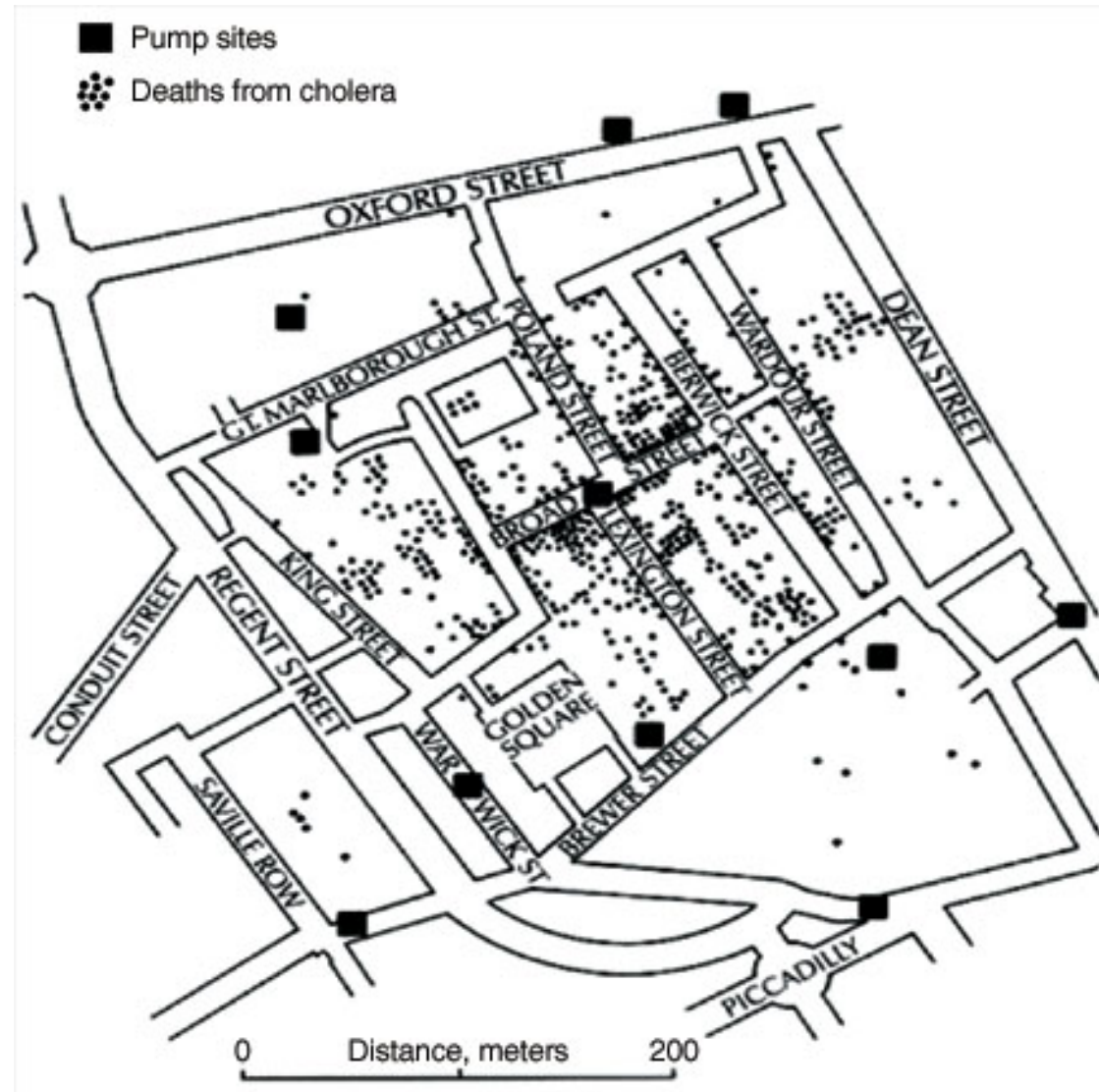


GIS Applications

Early application in epidemiology:

Dr. John Snow's map of cholera outbreaks in London, 1854.

Deaths were concentrated near Broad Street Pump, which was adjacent to a cesspit.

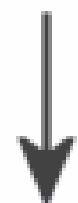


Risk Analysis

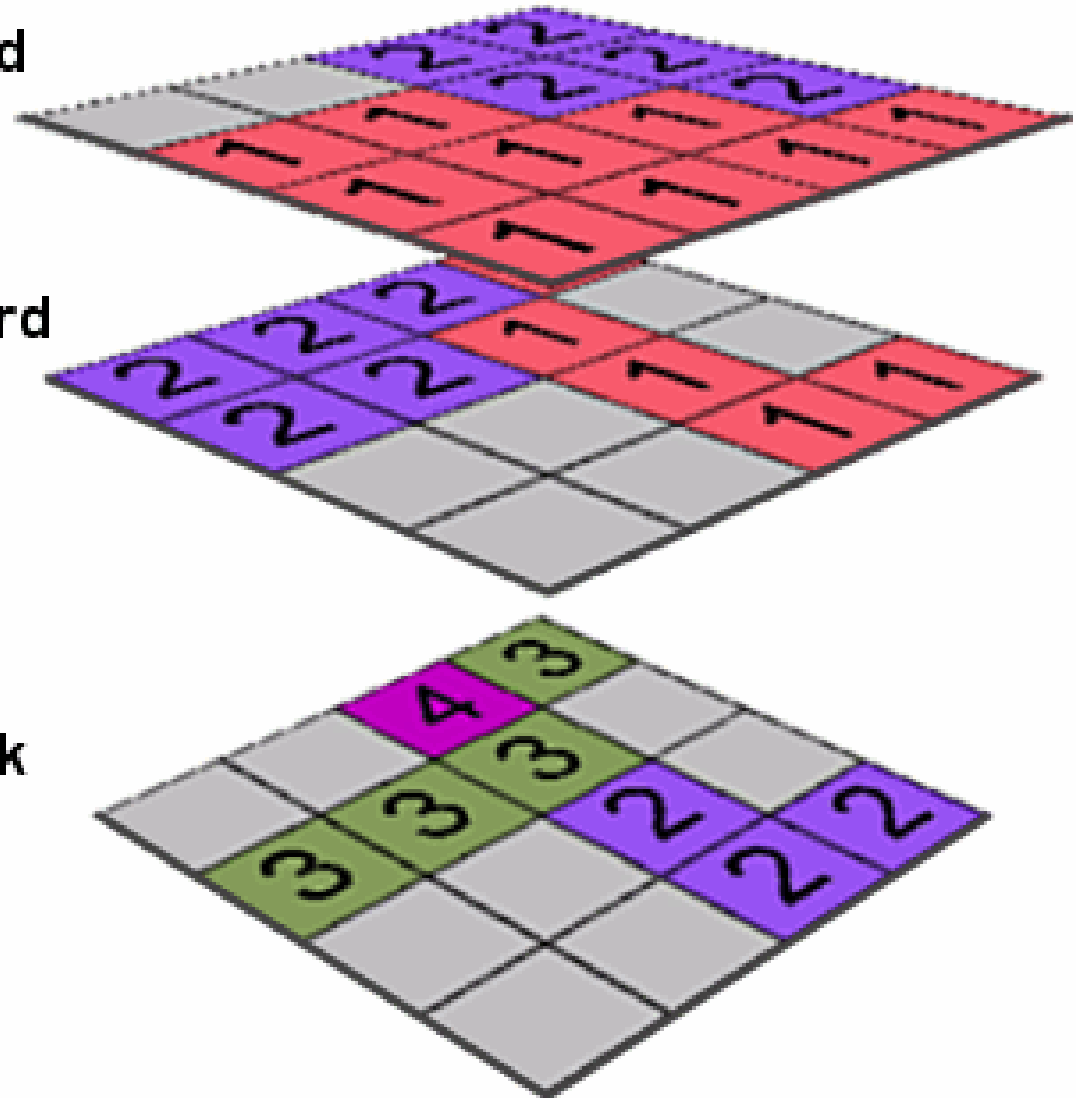
Fire hazard

+

Flood hazard

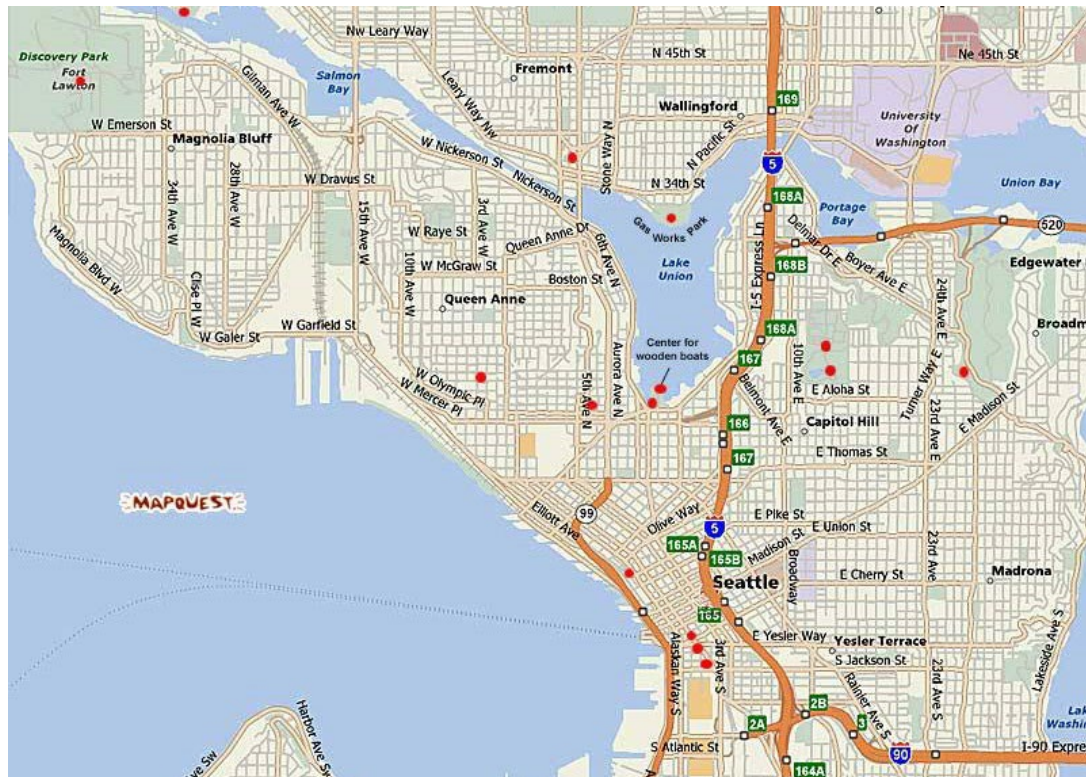


Hazard risk



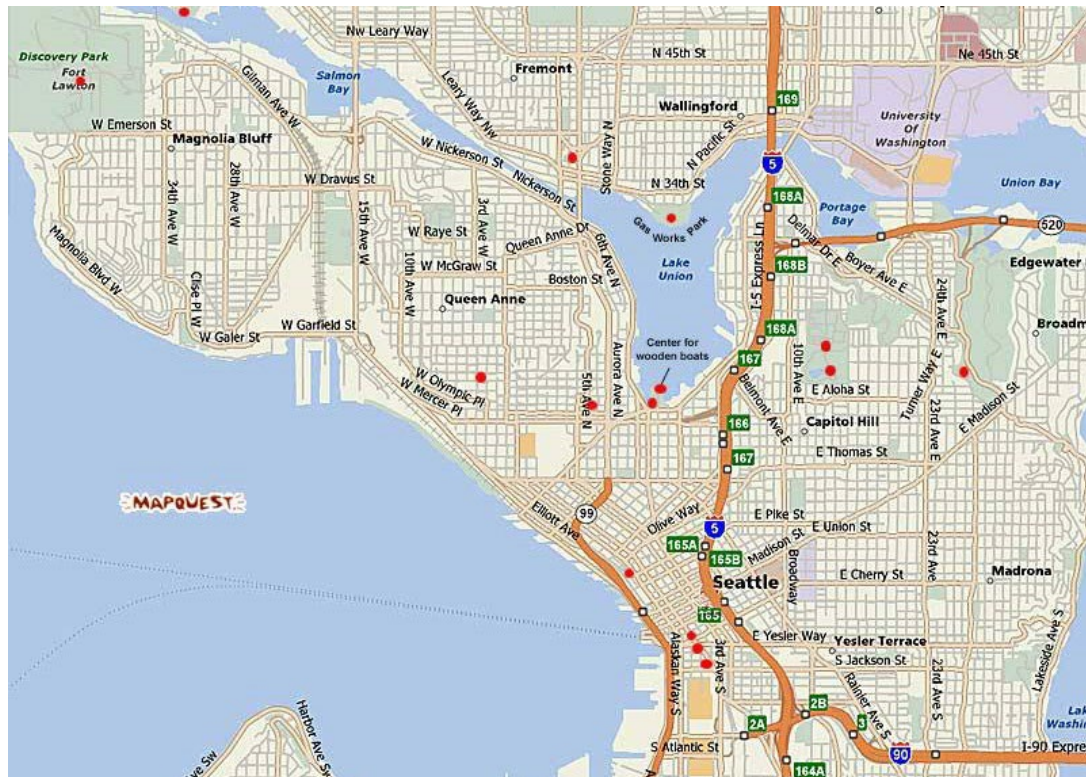
Suitability analysis example: Where's the best location for a new doggie daycare in Seattle?

Nap time



Where's the best location for a new doggie daycare in Seattle? What factors might be important?

Nap time

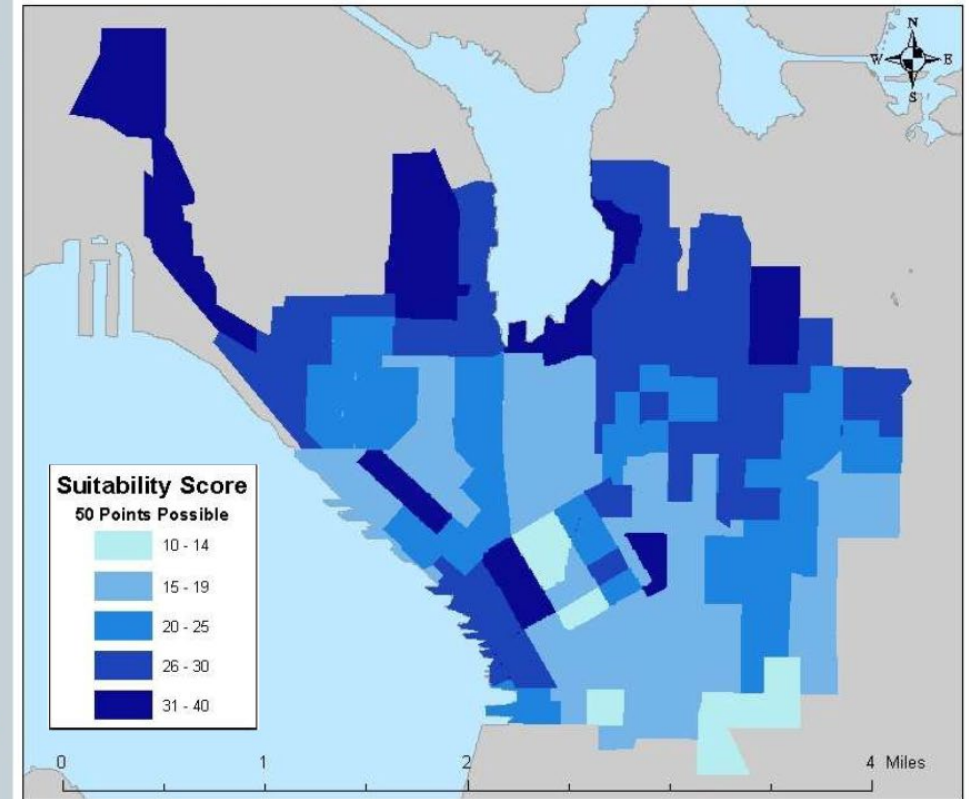


Customer Suitability

Demographic Layer

Combined Criteria:

- Median Household Income
- Average Age
- Percent of Condominiums
- Percent of Professionals
- Annual Spending on Pets

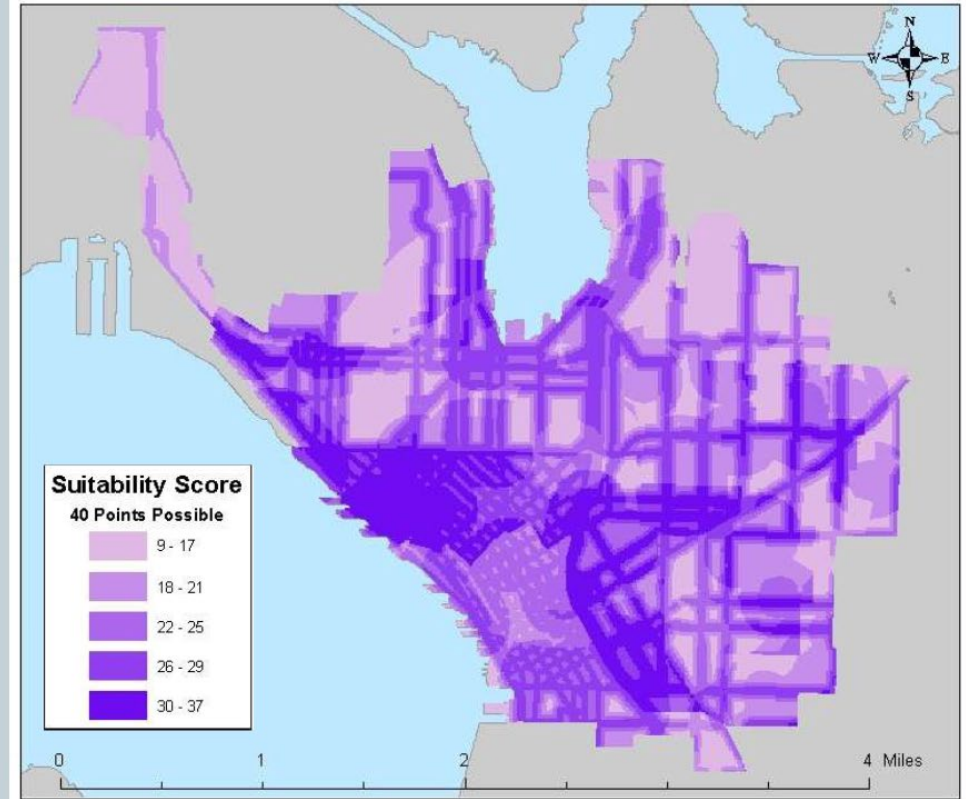


Infrastructure Layers

Distance Suitability

Combined Criteria

- Distance to competition
- Distance to Parks
- Distance to Arterials
- Proximity to Central Business District

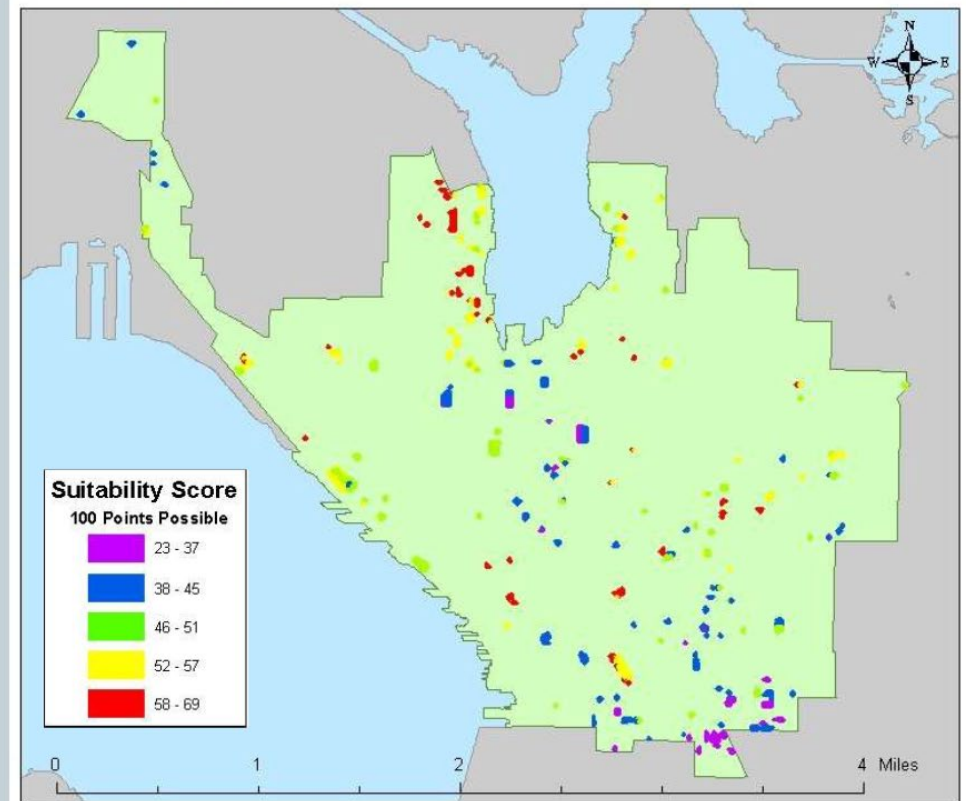


Suitability Model

Overall suitability is a combination of demographic and infrastructure layers.

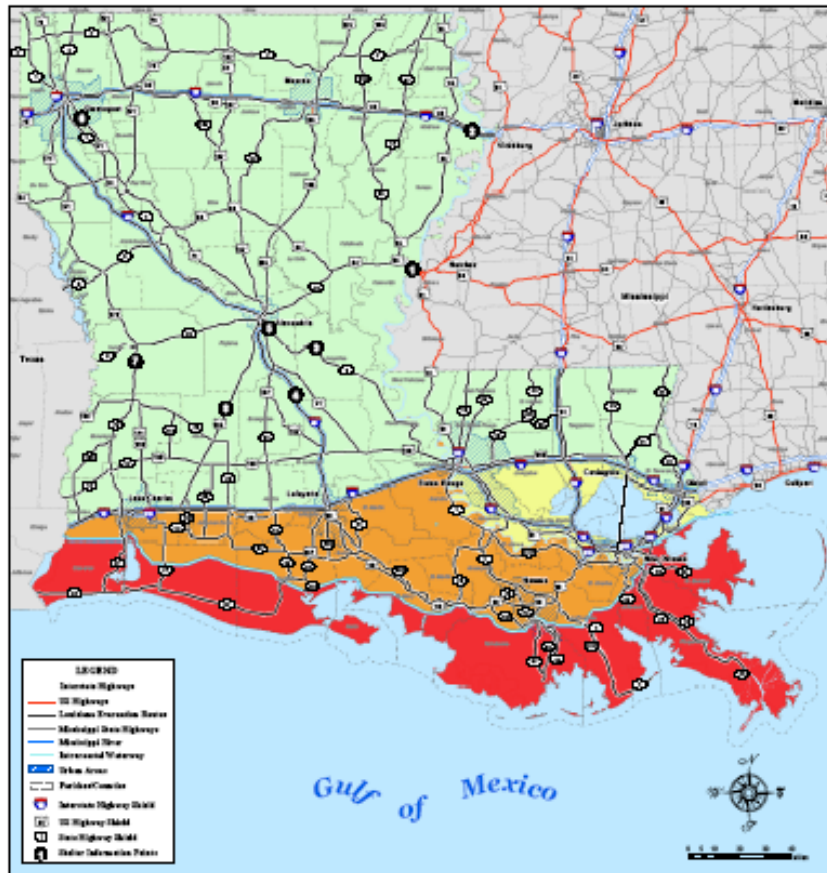
Parcel Suitability

After combining Customer Suitability, Distance Suitability and parcel criteria, you end up with a map of potential properties that meet all of your requirements.



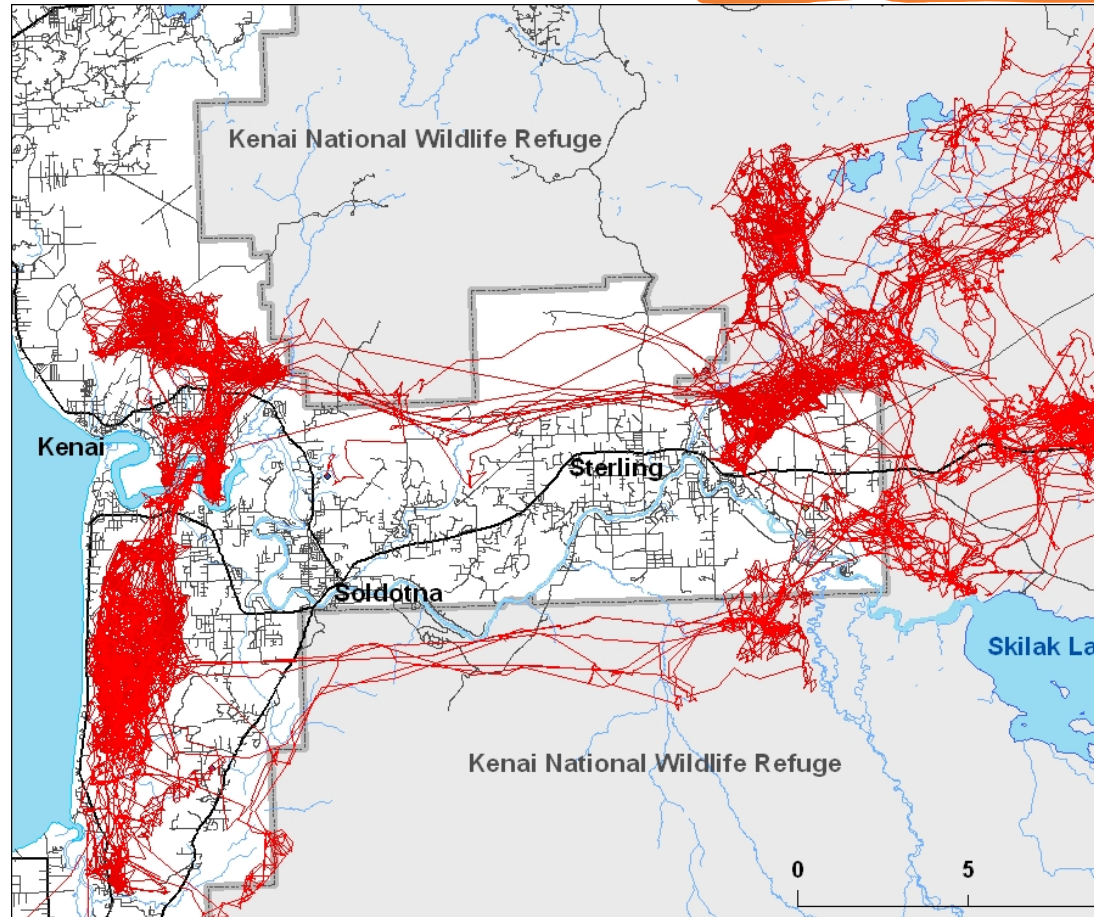
Example: Emergency Planning

LOUISIANA EMERGENCY EVACUATION MAP



- Priority evacuation sites in Louisiana
- What information could the priority levels be based upon?

Animal Movement: What applications could this map have?



Map of the day: Visualization

wind map

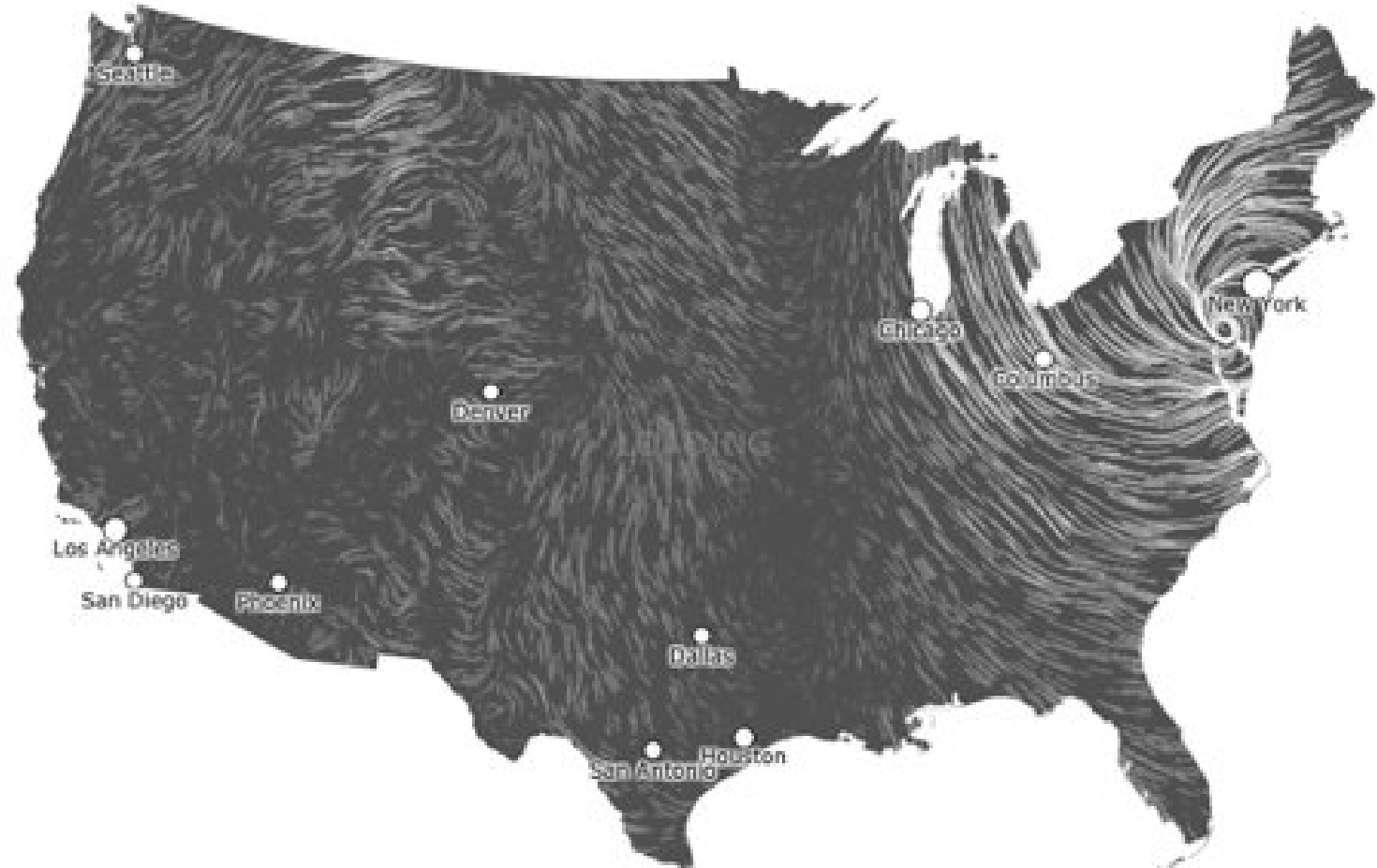
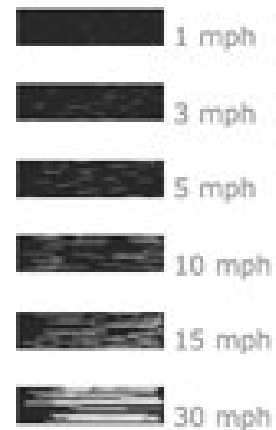
October 29, 2012

9:59 pm EDT

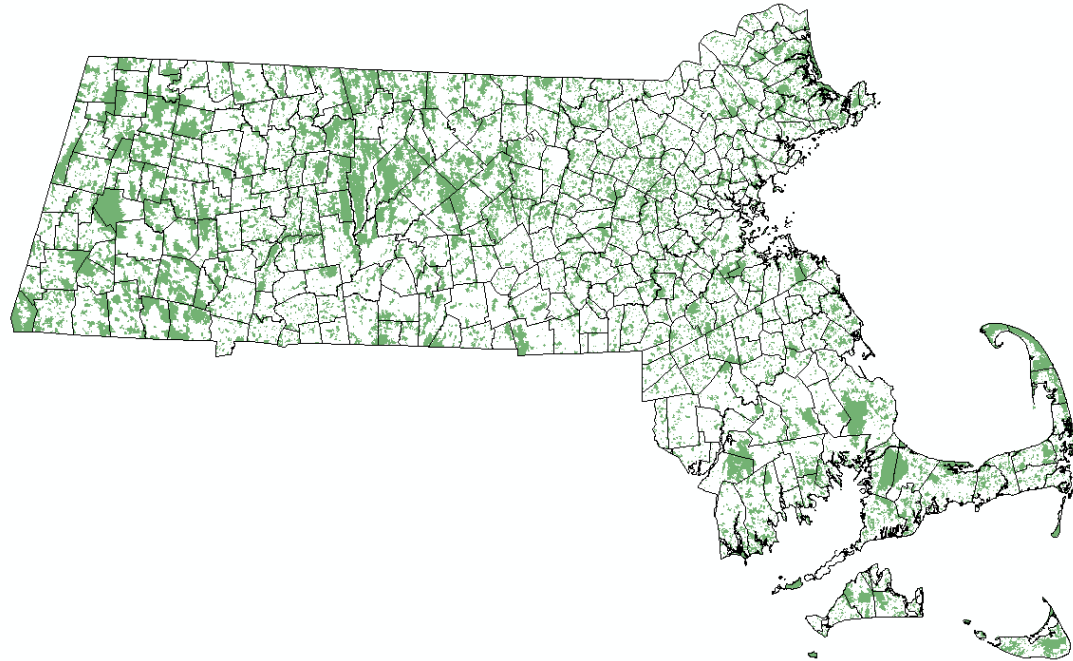
(time of forecast download)

top speed: 45.1 mph

average: 9.3 mph



Data exploration (in ArcGIS)



Protected lands in Massachusetts is a spatial dataset that you can download from MassGIS.

You'll get a chance to use this data layer in a lab!

For next
session:



Spatial Data Basics.



Into To Cartography.



Intro to Midterm and Final Projects.