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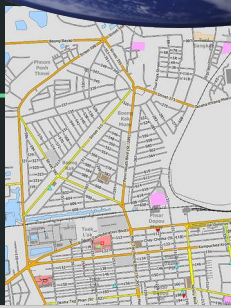
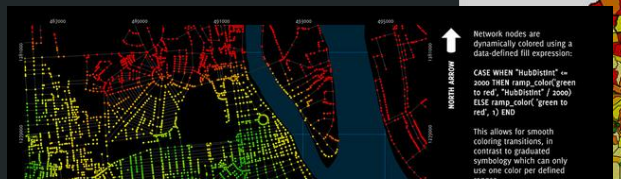
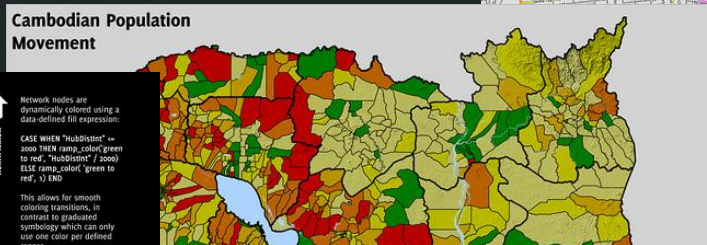
Introduction to Geographic Information Systems

DMDS Workshop

Jay Brodeur
2018-02-08







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Today's Outline

- Introduction to Geographic Information Systems (GIS)
- Basic fundamentals of GIS and geospatial analyses
- Introduction to Quantum GIS (QGIS)
- Hands-on Problem-Solving Assignments

Today's Objectives

By the end of this workshop you should be able to:

- Describe the components and basic functionality of GIS
- Communicate the range of uses for GIS
- Demonstrate basic GIS operation skills
- Make some effective (and attractive) maps!

Introduction to QGIS

What is GIS?

- **G**eographic **I**nformation **S**ystem
- A system to assemble, store, manipulate, analyze, manage and present ***geographically referenced data***
  - Data associated with or identified by their location
- A digital representation of real-world geographic attributes:
  - Location
  - Attributes
  - Spatial relationships

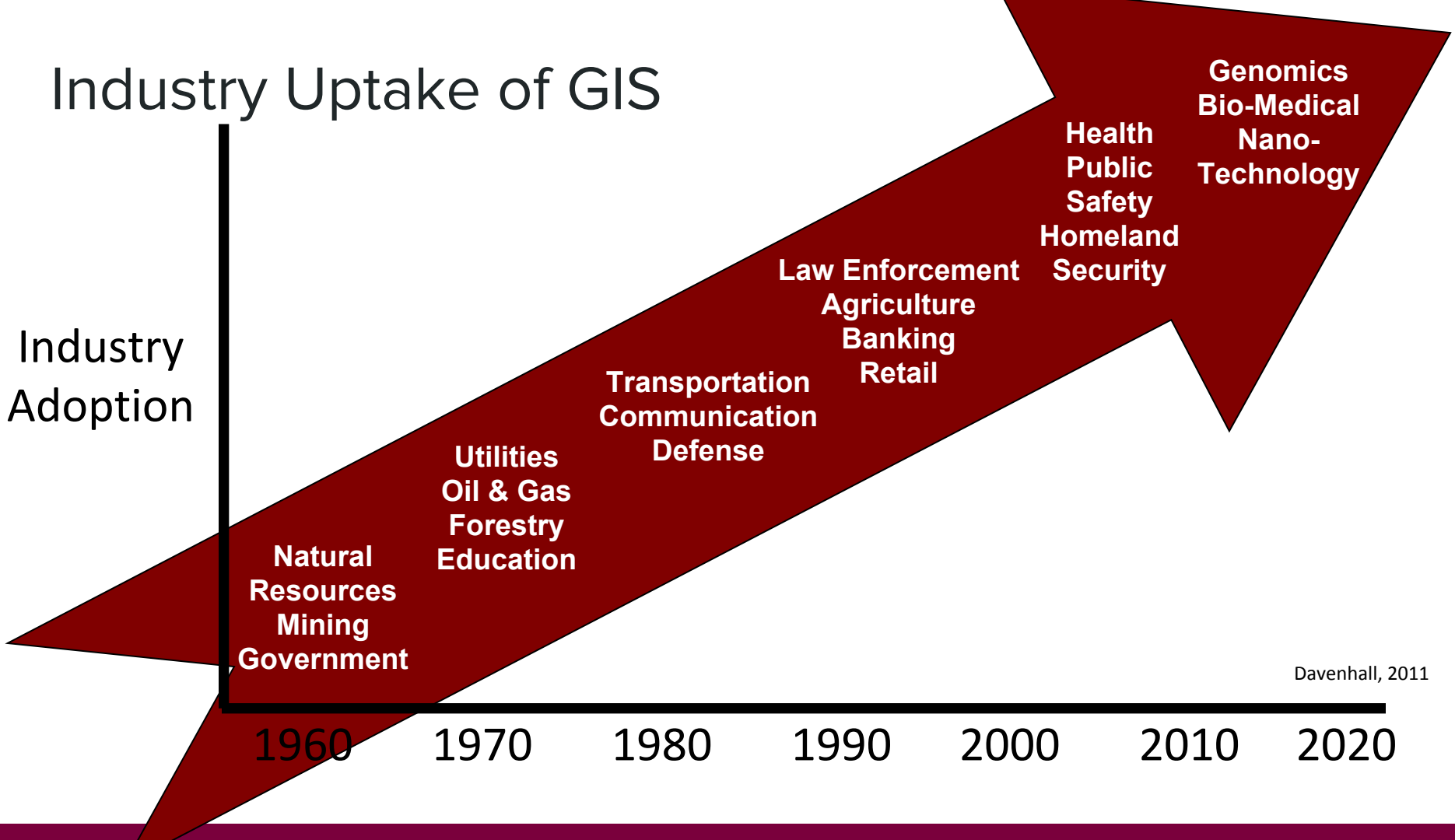
GIS Components

1. Hardware
2. Software
3. Data
4. Applications & Methods
5. People (developers and users)

History of GIS

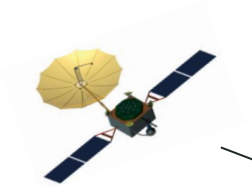
- Made in Canada!
  - 1960 by Dr. Roger Tomlinson for CLI data
  - Canada Geographic Information System (CGIS)
- Developed for wider use through ‘70s & ‘80s
  - CAD, ESRI, MapInfo – commercial software
  - MOSS, GRASS – open-source (public domain)
- Rapid growth and extension of use in ‘90s & ‘00s

Industry Uptake of GIS



Davenhall, 2011

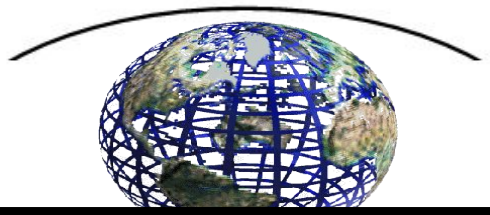
Geospatial Technology (AKA Geomatics)



Global Positioning Systems
(location and navigation)

Geographic Information Systems
(map and analyze)

Remote Sensing
(measure and classify)



One of the three "mega technologies" for the 21st century and promises to forever change how we conceptualize, utilize and visualize spatial relationships in scientific research and commercial applications, and general usage (U.S. Dept of Labor)

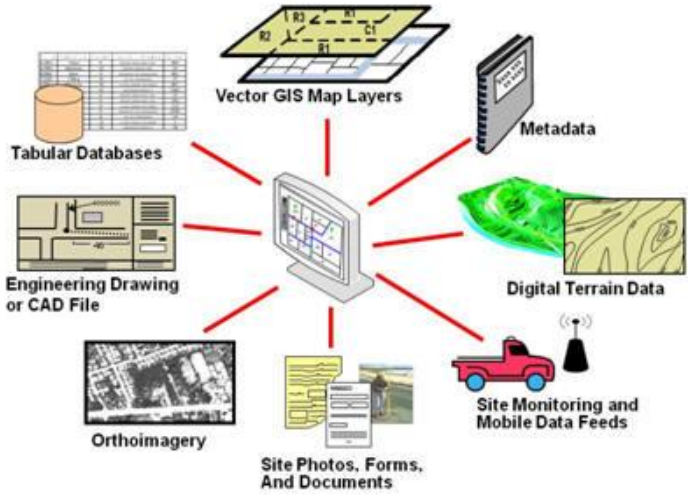
For more: http://en.wikipedia.org/wiki/Geomatics

Applications for GIS

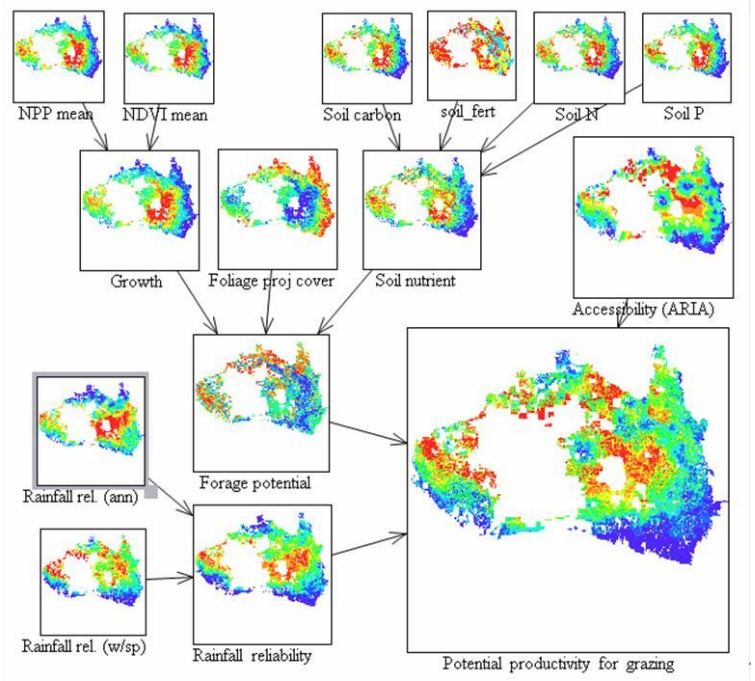
Using GIS to solve ‘real-world’ problems

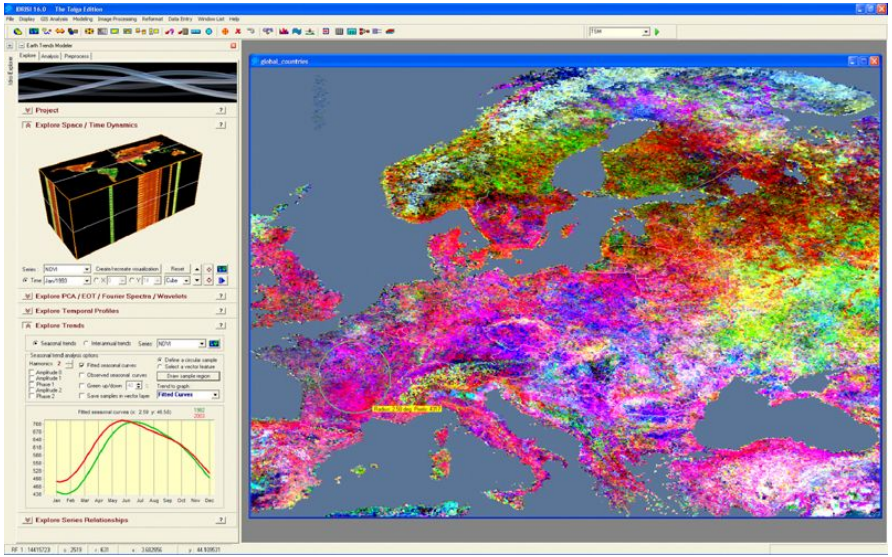
Data Management

- Collecting geospatial data
- Compiling diverse types of geographical & non-geographical data
- Searching / Querying / Retrieving data from databases

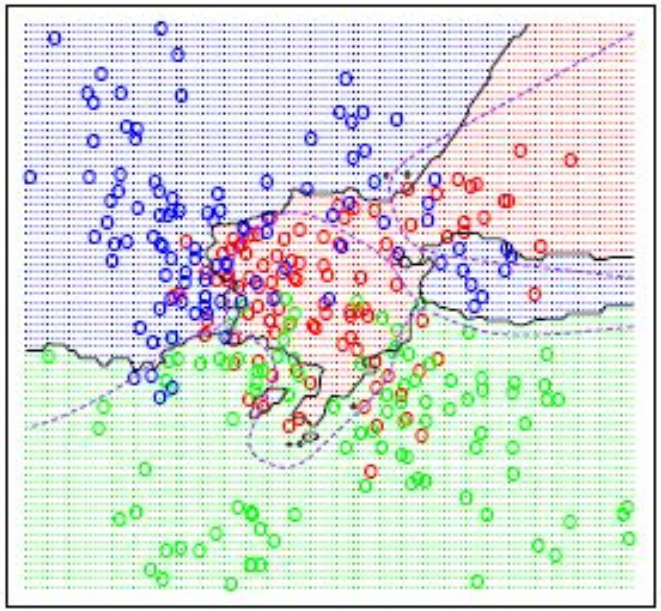


Multi-Criteria Analyses & Decision-Making

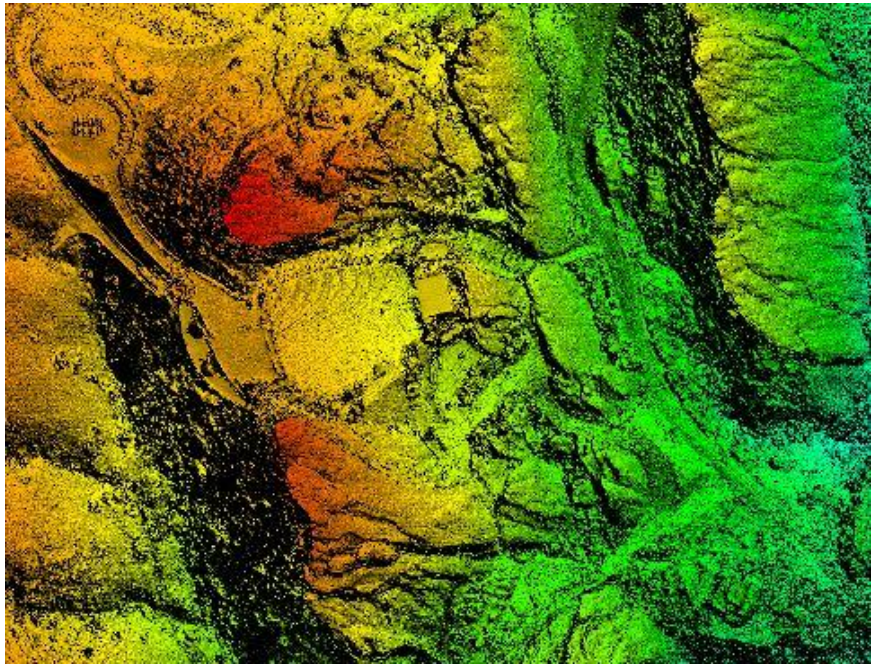




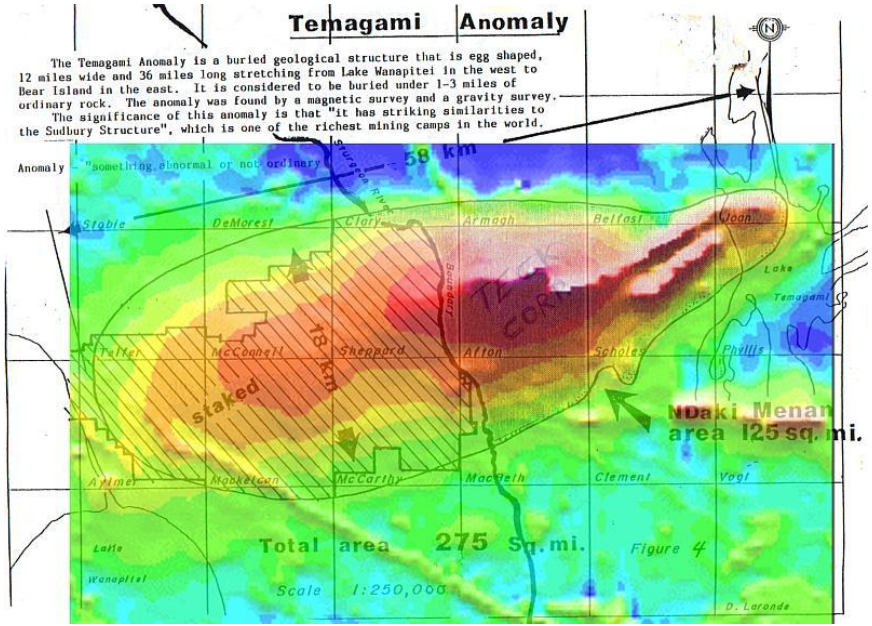
Geospatial Analyses / Geostatistics

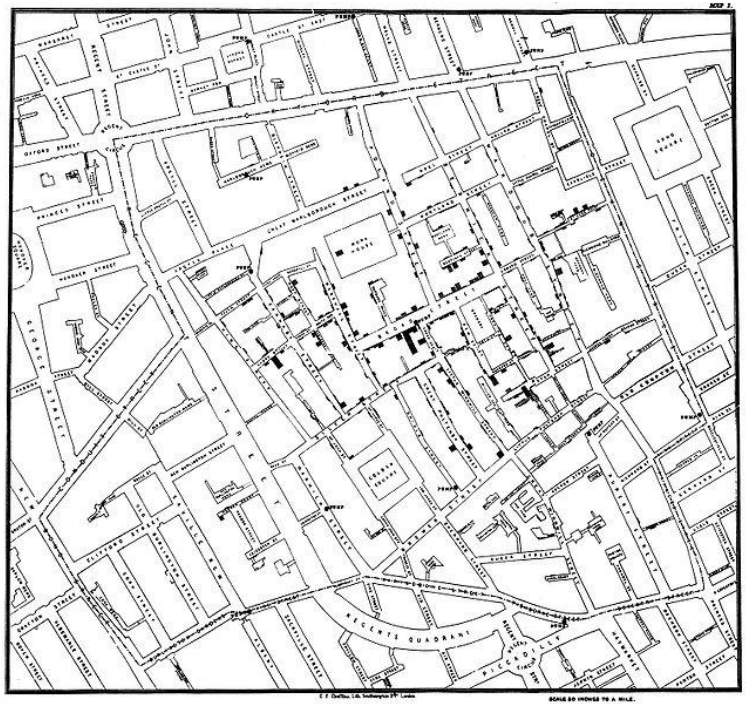


PSU, 2013

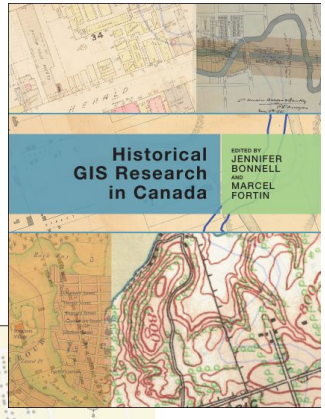


Data Visualization and Exploration





Historical GIS



http://uofcpress.com/books/9781552387085

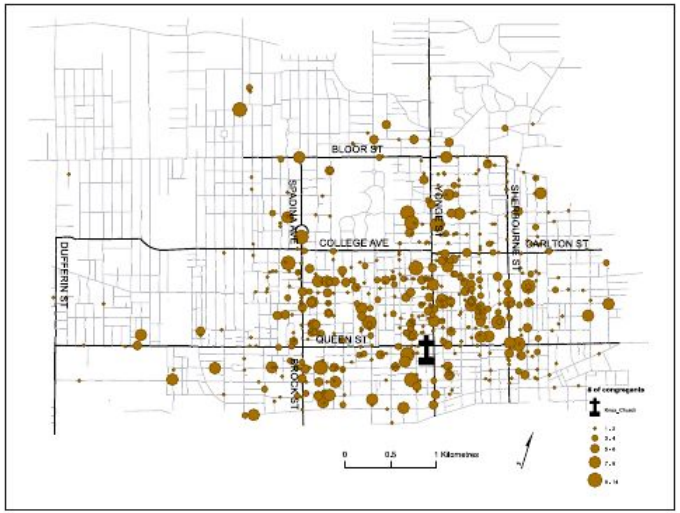


Fig. 4.3. Number of Knox congregants by address, 1887. (Sources: 1884 Toronto Streets: Adaptation of DMTI rte 2010; Knox Presbyterian Church Congregant Addresses: Knox Presbyterian Congregation Rolls 1882–1887.)

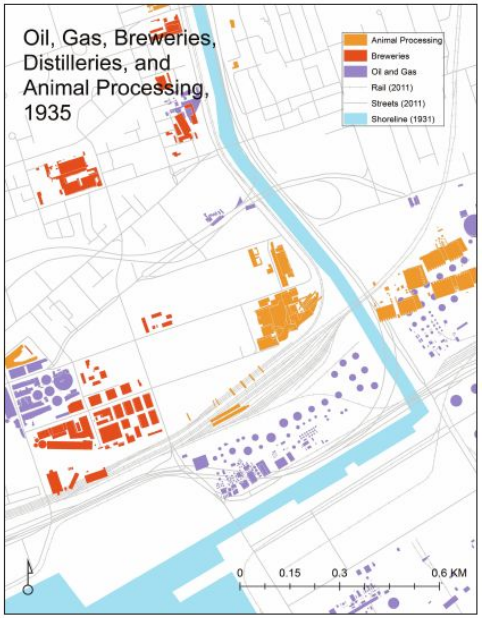


Fig. 3.5. Oil and gas, breweries, and animal processing, 1935. (Roads and Railroads from DMTI Spatial Inc. CanMap RouteLogistics 2011.3.)

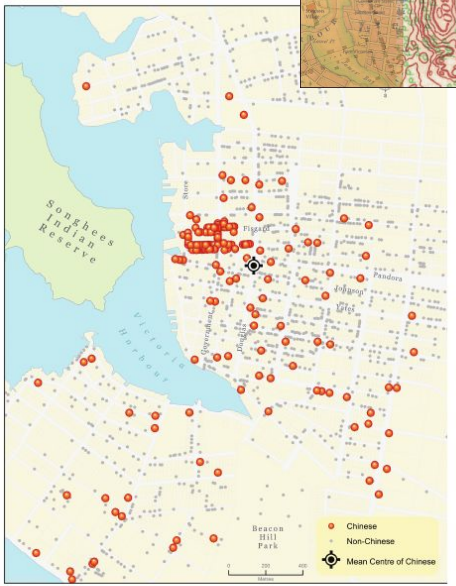
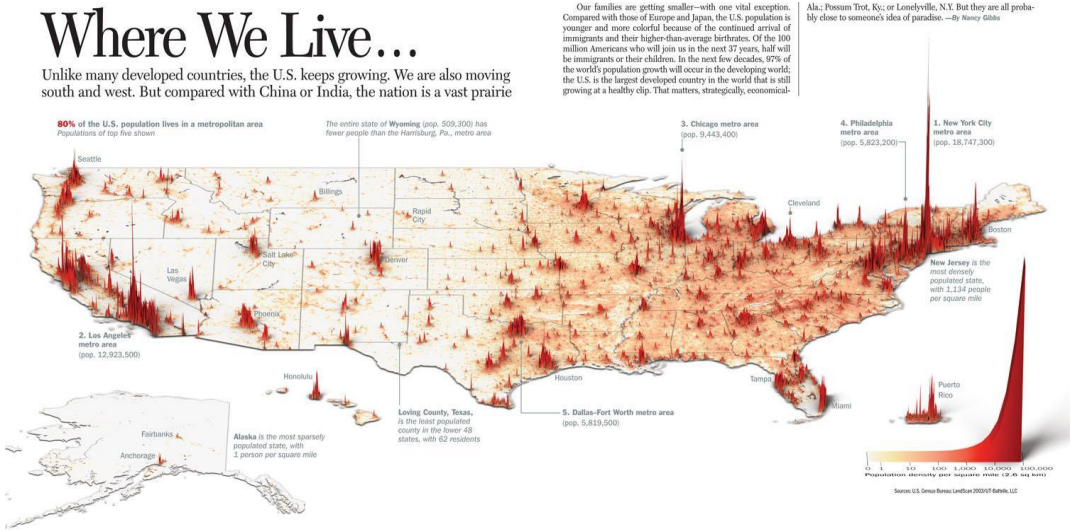
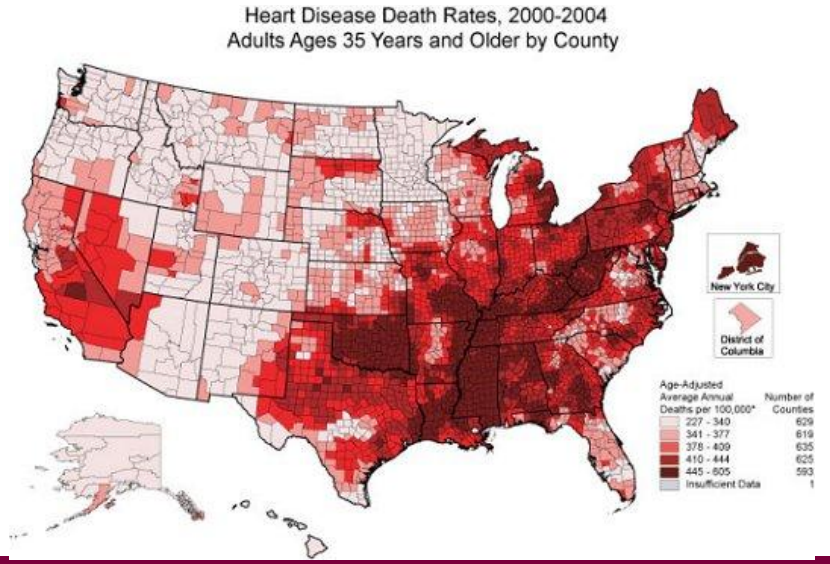


Fig. 1.9. Victoria population, 1891, showing residences of Chinese and non-Chinese. Source: Canada Census, 1891 with addresses provided by the City of Victoria 1891 Check Census in the BC Archives (Add Mss 1908) and Williams' Illustrated Official British Columbia Directory for the Cities of Victoria, Vancouver, Nanaimo and New Westminster, 1892 *compiled by the firm of R. T. Williams of Victoria. The directory was compiled in the fall of 1891. Both the census and directory are available on line at www.vihistory.ca.*

Mapping / Information Dissemination





Common GIS Software

- Many, MANY types of GIS software
- Different tools for different purposes
  - Full-featured vs. specialized
  - Open-source vs. closed-source
  - Free vs. licensed
  - User-friendly vs. technical
  - Online vs. standard desktop

Quantum GIS (QGIS)

- Free and open-source GIS software
- User-friendly, fully-functional; relatively lightweight
- Product of the Open Source Geospatial Foundation (OSGeo)
- Built in C++; uses python for scripting and plugins
- Version 1.0 released in 2009
- Current version: 2.18.14; Long-term release (LTR): 2.18.14

GDAL - Geospatial Data Abstraction Library

www.gdal.org

SAGA - System for Automated Geoscientific Analyses

saga-gis.org/

GRASS - Geographic Resources Analysis Support System

www.grass.osgeo.org

QGIS - Quantum GIS

qgis.org

GeoTools

www.geotools.org

Helpful QGIS Tutorials and Resources

- QGIS Tutorials: http://www.qgistutorials.com/en/
- QGIS Quicktips with Klas Karlsson: https://www.youtube.com/channel/UCxs7cfMwzgGZhtUuwhny4-Q
- QGIS Training Guide: https://docs.qgis.org/2.8/en/docs/training_manual/

Geospatial Data Fundamentals

Representing real-world geographic information in a computer

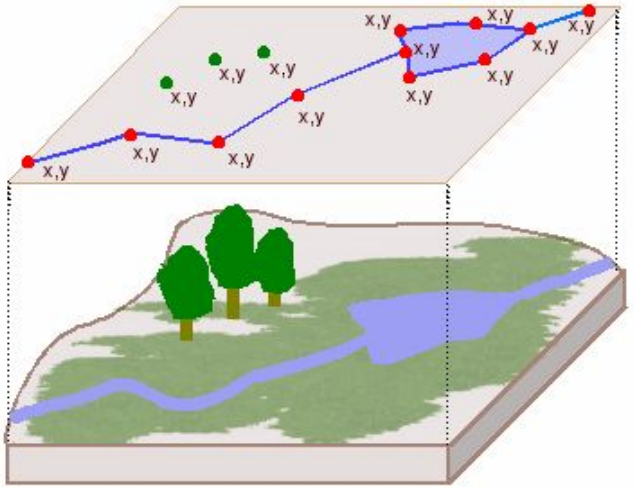
Data Models

Data models are used to represent real-world geospatial features and objects in a digital format

Most common methods:

- Vectors
- Rasters

Vector Data Model



www.geography.hunter.cuny.edu

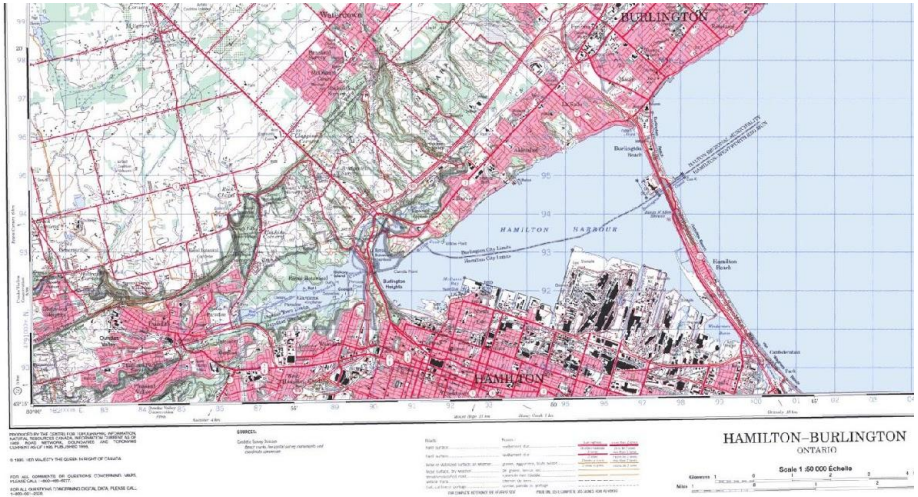
Features represented by:

1. **Points** – (x,y,z) coordinates
    - Hospitals, measurement points, cities
2. **Lines** – Series of connected points
    - Rivers, roads, transects
3. **Polygons** – Areas enclosed by a self-connecting line
    - Lakes, countries, buildings, cities

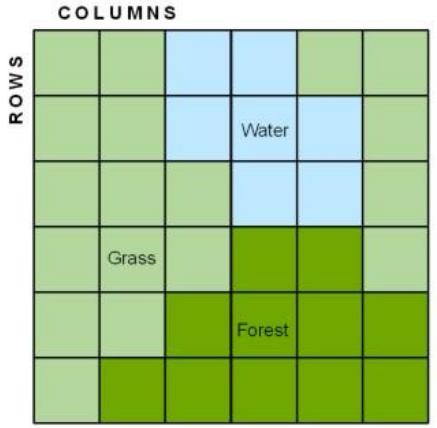
Vector Data

Courtesy: Harvard Map Collection

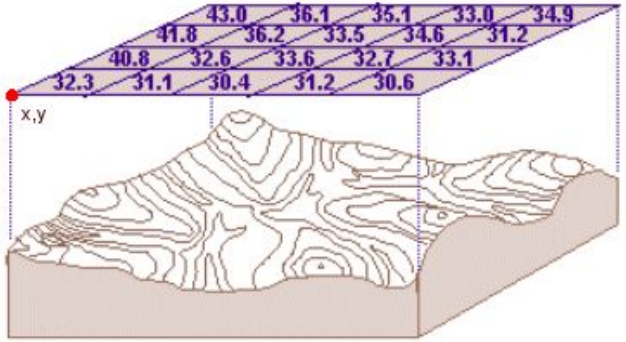
- Useful for clearly-defined objects
- Provides spatial relationships
- Can be scale-dependent



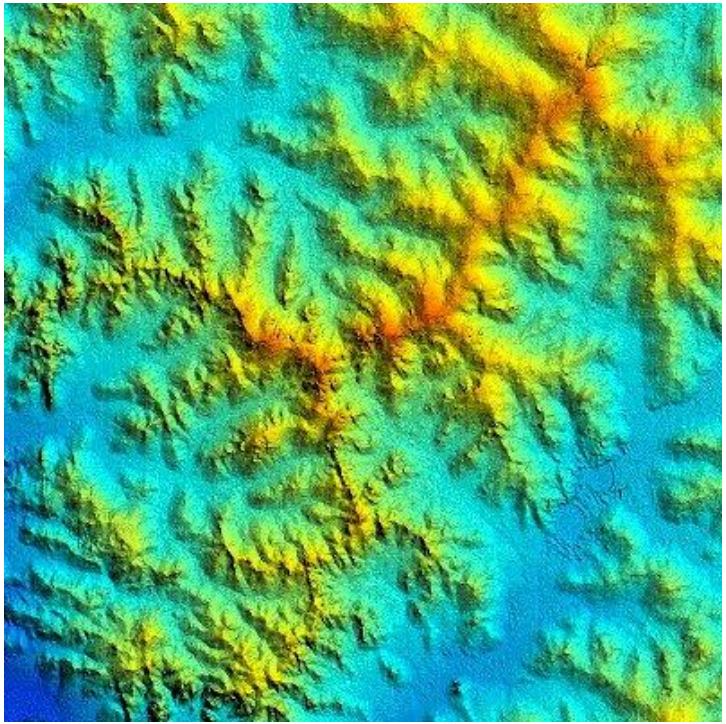
Raster Data Model

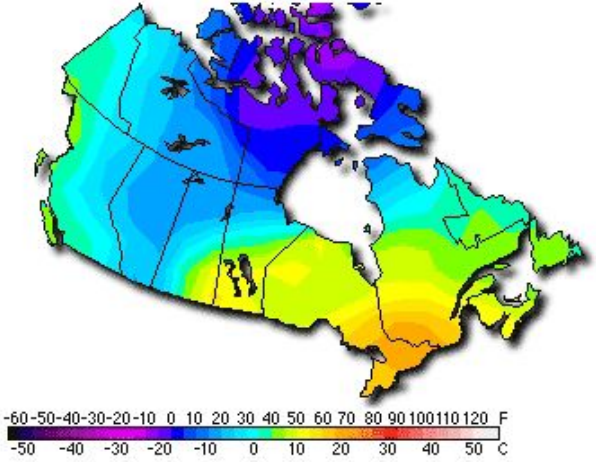


- Regular grid of cells
- Each cell = specified ground area
  - (Spatial resolution)
- Values assigned to cells
  - Categorical (land use, classification)
  - Continuous (elevation, temperature)
- E.g. Satellite imagery,
  digital elevation models (DEMs)



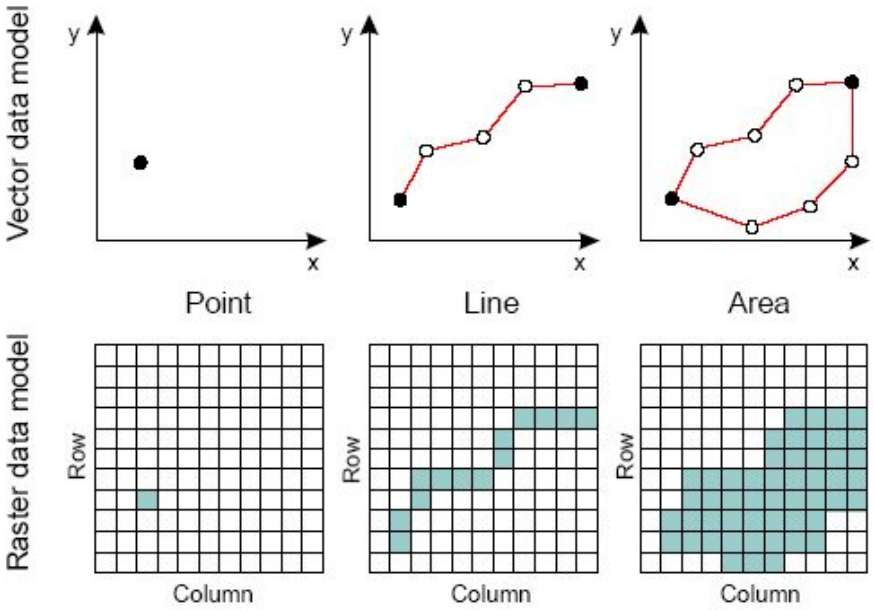
Raster Data

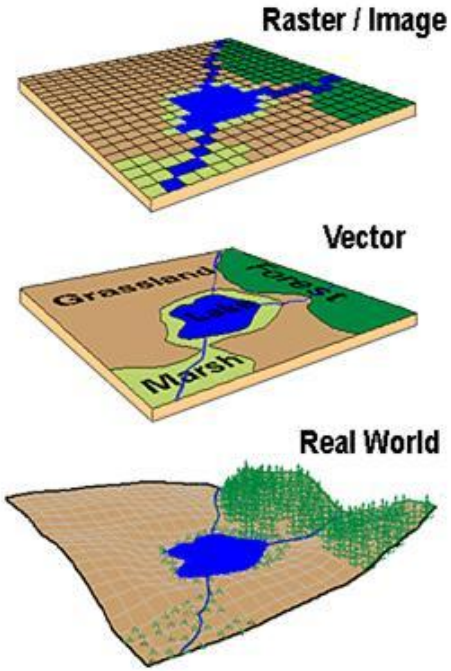



-60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90 100 110 120 F
-50 -40 -30 -20 -10 0 10 20 30 40 50 C


Google

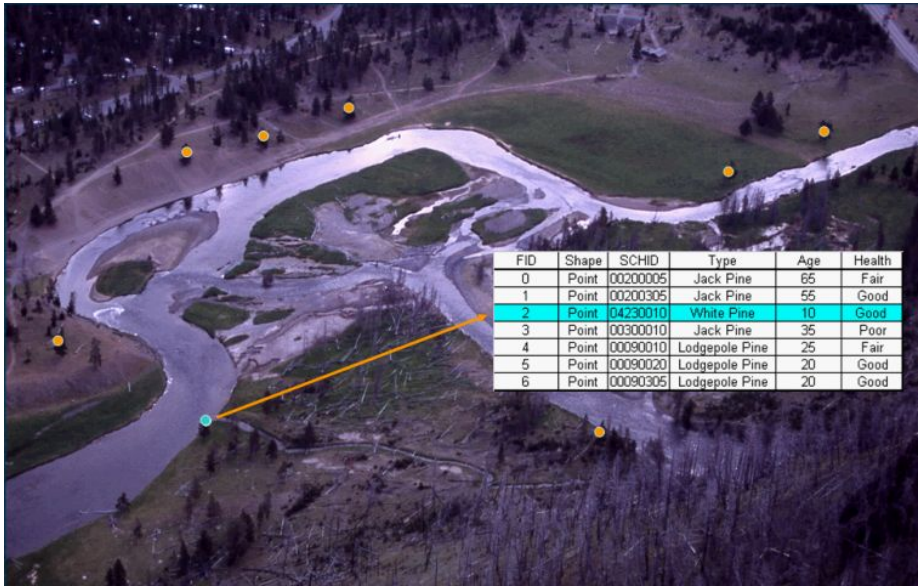
Raster vs. Vector





Attributes

- Link non-geographic information to geographic data
- Provide supplementary and contextual information



Coordinate Reference Systems

Referencing the location of objects on the Earth’s surface

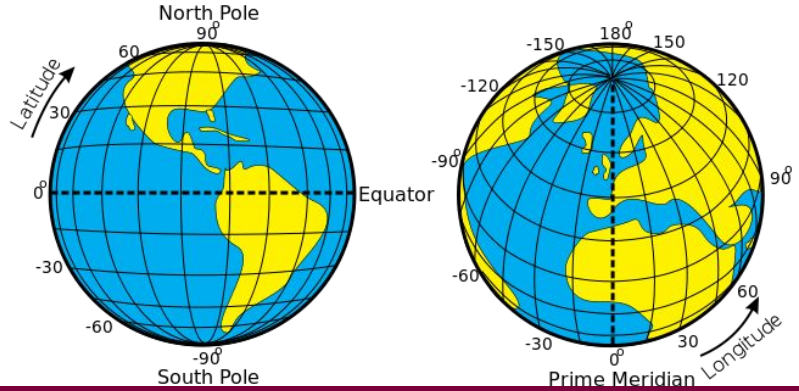
Coordinate Reference Systems (CRS)

A means of expressing the absolute location of a feature

- **Geographic** – expressed as angles (e.g. latitude, longitude)
- **Projected** – expressed as distances from a reference point on a plane

Geographic Coordinate Systems

- Locations expressed as angles from an anchor point
- Network of intersecting lines (e.g. latitude, longitude, elevation)
- Reference system for a curved Earth
- Mathematical operations on multiple points are complicated
- Based on a geodetic datum
  - MANY datums exist
  - World Geodetic System - WGS 84
  - North American Datum - NAD 83



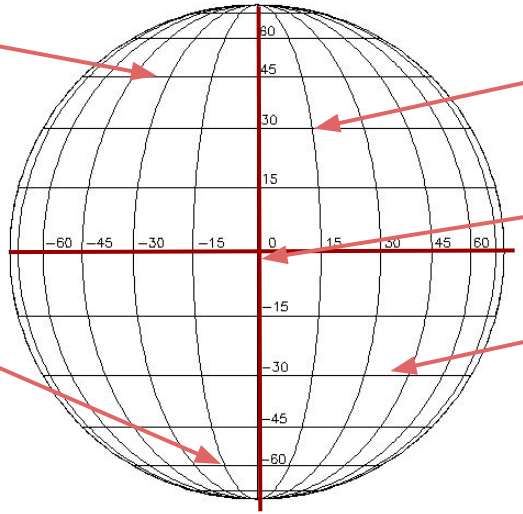
Geographic Coordinate Systems

1. Reference to a Geographic Coordinate System (lat / long)
   - Degrees East and North of (0°, 0°)

-45° E, 45° N

(-45° E = 45° W)

-15° E, -60° N



15° E, 30° N

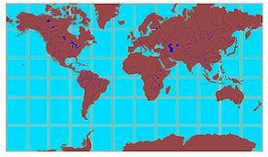
Origin (0° E, 0° N)

35° E, -30° N

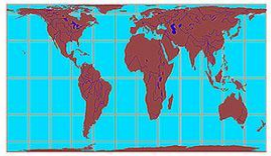
(-30° N = 30° S)

Projected Coordinate Systems

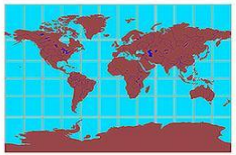
- Projections of the round Earth to a flat surface → Maps
- Express location as distance from an anchor point
  - Also based on a datum
- All projections preserve and distort some surface features
  - Area, shape, direction, bearing, distance, scale



Mercator Projection



Gall-Peters Projection

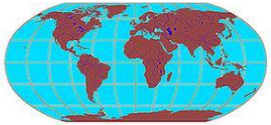


Miller Cylindrical Projection

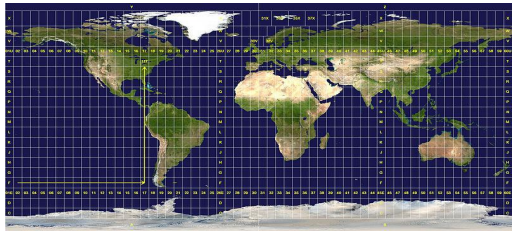
Mollweide Projection

Goode's Homolosine Equal-area Projection

Sinusoidal Equal-Area Projection



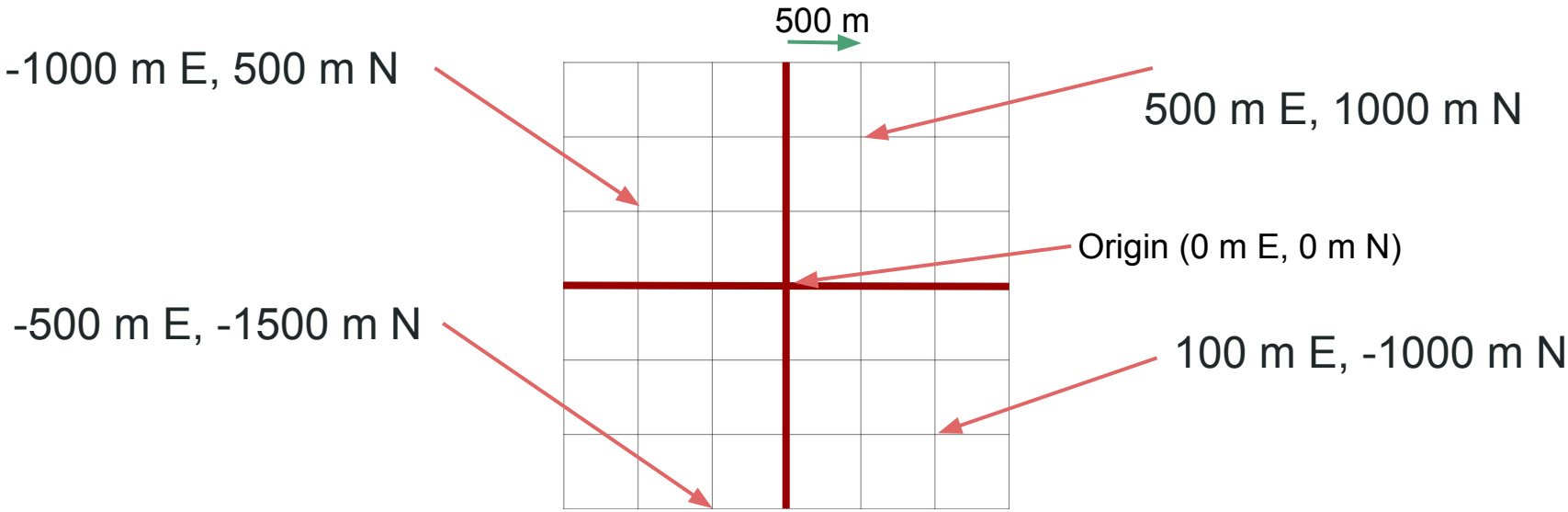
Robinson Projection



Universal Transverse Mercator (UTM)

Projected Coordinate Systems

2. Reference to a Projected Coordinate System
   - Distance (e.g. metres) East and North of a selected origin



Where to Find Geospatial Data

Getting Data

Consortial/subscription data is made available through Scholars Geoportal

- http://geo.scholarsportal.info/

Municipal open data portals:

- City of Hamilton Open & Accessible Data
  - http://www.hamilton.ca/city-initiatives/strategies-actions/open-accessible-data
- City of Toronto Open Data Catalogue
  - http://www1.toronto.ca/wps/portal/contentonly?vgnextoid=1a66e03bb8d1e310VgnVCM10000071d60f89RCRD
  - http://goo.gl/o0slUt

Hands-on!

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Task 1: Making a map with open data

Objective:

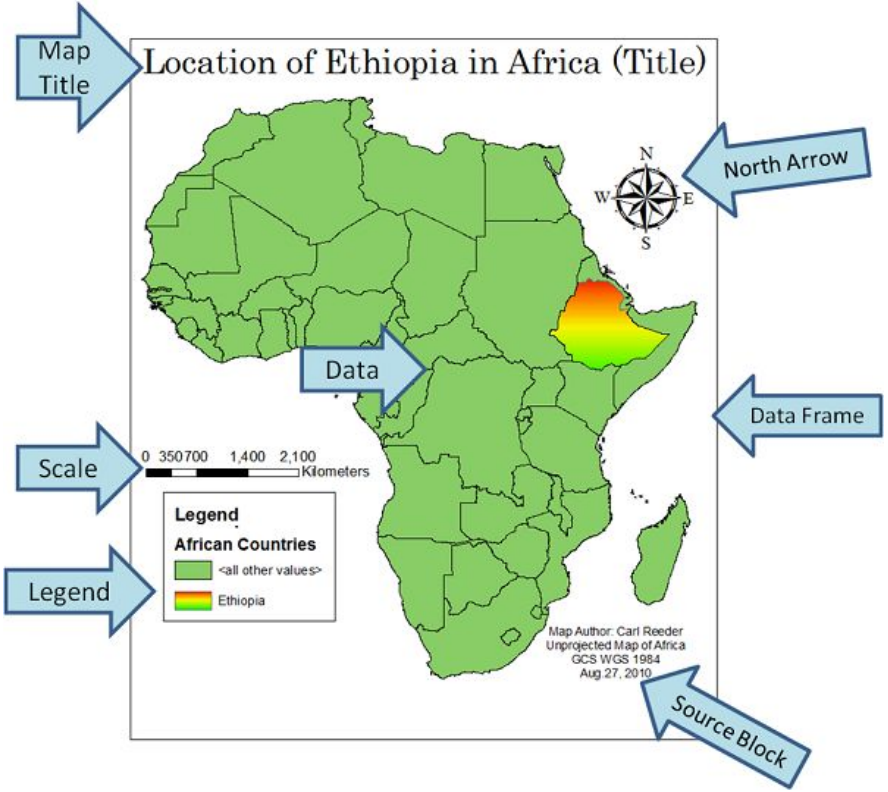
Use freely-available (open) data to create a map of a Hamilton neighbourhood / area of your choice

Topics Covered:

- The QGIS Interface
- Geospatial data
- Layer styling
- Labeling
- Map elements
- Map composition

Fundamental Map Elements

1. Data
2. Title
3. Frame (Neatline)
4. Scale
5. Legend
6. North Arrow
7. Source Information
8. Author, date, projection, ©,etc.



Other Important Map Considerations

- Maximize clarity
- Consider your audience
- Design and style choices are important
  - Colour, line thickness, symbols, etc.

Task 1b: Downloading new data | adding it to your map

1. Navigate a browser to Scholars Geoportal: http://geo.scholarsportal.info/
2. Search for a vector (point, line, or polygon) file and view it
3. Download the file of interest
4. Unzip it and add to your map

Re-publish your map

Task 2: Importing & mapping tabular data

Objective:

Import tabular census data to visualize demographic / socio-economic distributions in Hamilton; Make a webmap

Topics Covered:

- ➢ Importing tabular data
- ➢ Table joins
- ➢ Creating choropleths
- ➢ Using QGIS plugins
- ➢ Web maps as base maps
- ➢ Making a webmap!

Task 3: Performing spatial Analyses

Objective:

Explore some spatial analysis tools and approaches

Topics / Processes Covered:

- Points in polygons
- Buffers
- Heatmaps

Task 4: Creating spatial data, Part II

Objective:

Geocoding to assign coordinates to features

Topics Covered:

- Importing tabular data
- Geocoding
- Using the MMQGIS plugin

Extra Stuff

Task 5: Georeferencing

Objective:

Turn an image with spatial extent (map, aerial photo, etc.) into a geospatial data layer

Topics Covered:

- Intro to mapwarper
- What is georeferencing?
- Ground control points
- Image transformation
- Vectorization?

Georeference

… “to associate something with locations in physical space”[1]

… [in GIS:] “the process of associating a physical map or raster image of a map with spatial locations”.[1]

[1]Wikipedia
http://en.wikipedia.org/wiki/Georeference

Aligning geographic data to a known coordinate system so it can be viewed, queried, and analyzed with other geographic data. Georeferencing may involve shifting, rotating, scaling, skewing, and in some cases warping, rubber sheeting, or orthorectifying the data.[2]

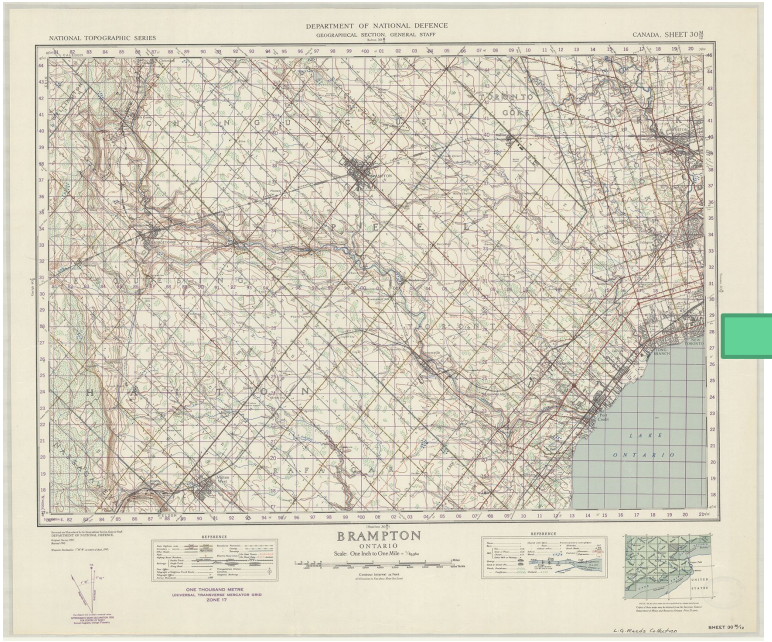
[2]ESRI GIS Dictionary
http://support.esri.com/sitecore/content/support/Home/other-resources/gis-dictionary/term/georeferencing

Georectification

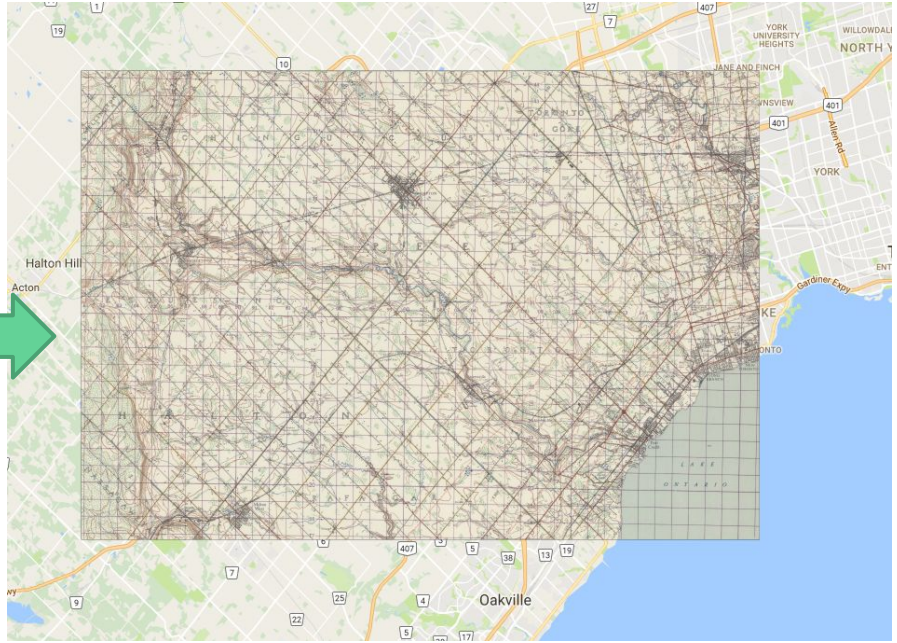
The digital alignment of a satellite or aerial image with a map of the same area. In georectification, a number of corresponding control points, such as street intersections, are marked on both the image and the map. These locations become reference points in the subsequent processing of the image.[1]

[1]ESRI GIS Dictionary
http://support.esri.com/sitecore/content/support/Home/other-resources/gis-dictionary/term/georectification

Target image



Projected image in a webmap



http://perec.mcmaster.ca/maps/OCUL/300ppi/

Target image

http://digitalarchive.mcmaster.ca/islandora/object/macrepo%3A33284

Projected image in GIS software

http://perec.mcmaster.ca/maps/apindex/

Why georeference/georectify maps and images?

Analyze

- Use GIS to evaluate spatial characteristics and relationships
- e.g. land-use change; boundary mapping; image processing

Visualize

- Explore information in a spatial context
- Explore & “mash-up” multiple information layers

Generate new data

- e.g. vectorizing georeferenced imagery

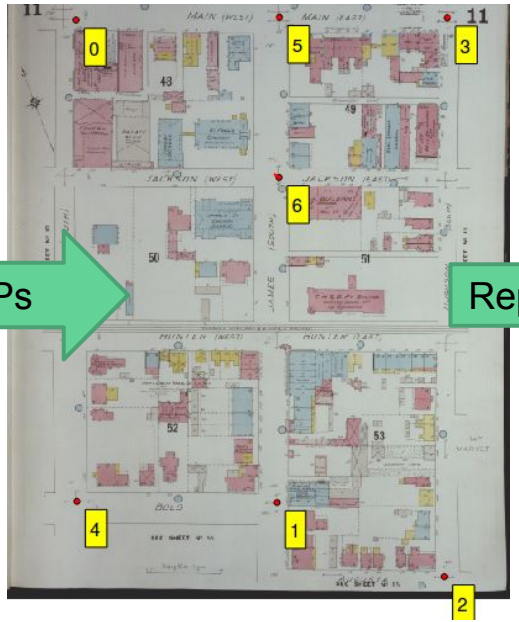
The process

Target image

Georeferenced image with ground control points (GCPs)

Georectified (projected) image in GIS software

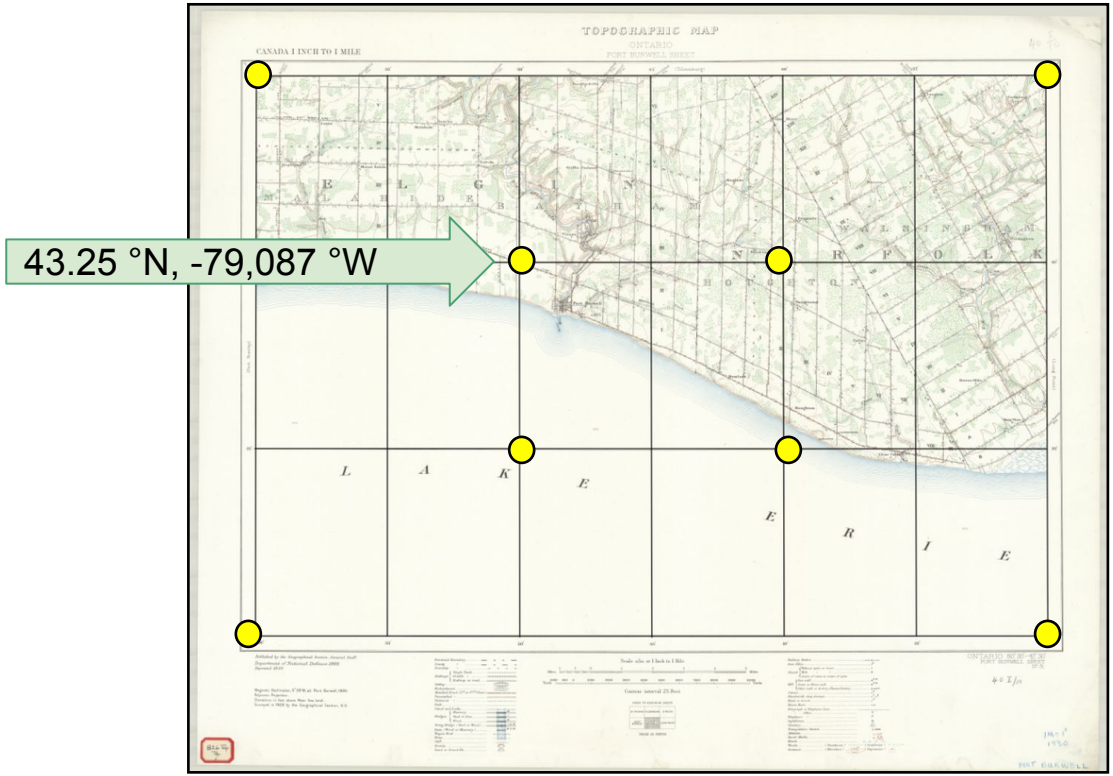
Add GCPs



Reproject

Setting GCPs using embedded coordinates

Map is georeferenced to its native coordinate reference system (CRS)



Setting GCPs using georeferenced map / data

Map is georeferenced to the reference data's coordinate reference system (CRS)

Transformation model and # of GCPs

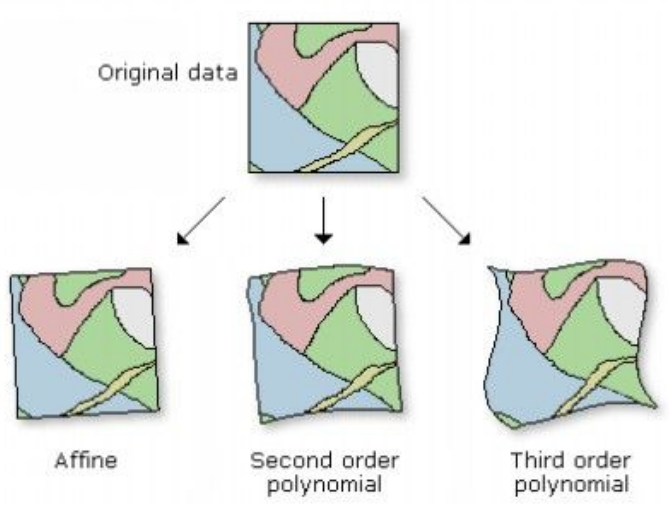
The # of GCPs required depends on your need for accuracy and the transformation model
(i.e. the flexibility for warping the map)

You can use:

Polynomial 3 if you've found 10 or more control points

Polynomial 2 if you've found 6 or more control points

Polynomial 1 if you've found 3 or more control points



Map Warper

“...is an open source map geo-rectification, warping and georeferencing application. It enables a user to upload an image, a scanned map or aerial photo for example, and by placing control points on a reference map and the image, to warp it, to stretch it to fit.”

Tim Warner’s Map Warper Github Page
https://github.com/timwaters/mapwarper

Step 1: Sign up, Sign in

Navigate to http://mapwarper.net/

- New users: Click on CREATE ACCOUNT
  - Create an account
  - Click on activation link in your new email message

- Registered users: SIGN IN

Step 1: Log in

Navigate to http://mapwarper.net/

SIGN IN with these credentials:

- Login: libgis@mcmaster.ca
- Pass: mapwarper

Step 2: Browse the maps

Click “BROWSE ALL MAPS”

Browse maps for our exercise

- Search Tags for ***macgisday***

Step 3: Getting familiar

Jay will introduce the site and demonstrate the process.

Step 4: Getting Started

Claim a map to georectify with Map Warper in this shared Google Sheet:

https://goo.gl/7yFqRf

Give it a try!

Task 4: Geocoding

Objective:

Use the MMQGIS plugin to assign coordinate information to a list of place names using an open gazetteer.

Topics Covered:

- Geocoding
- MMQGIS plugin
- Custom layer styling