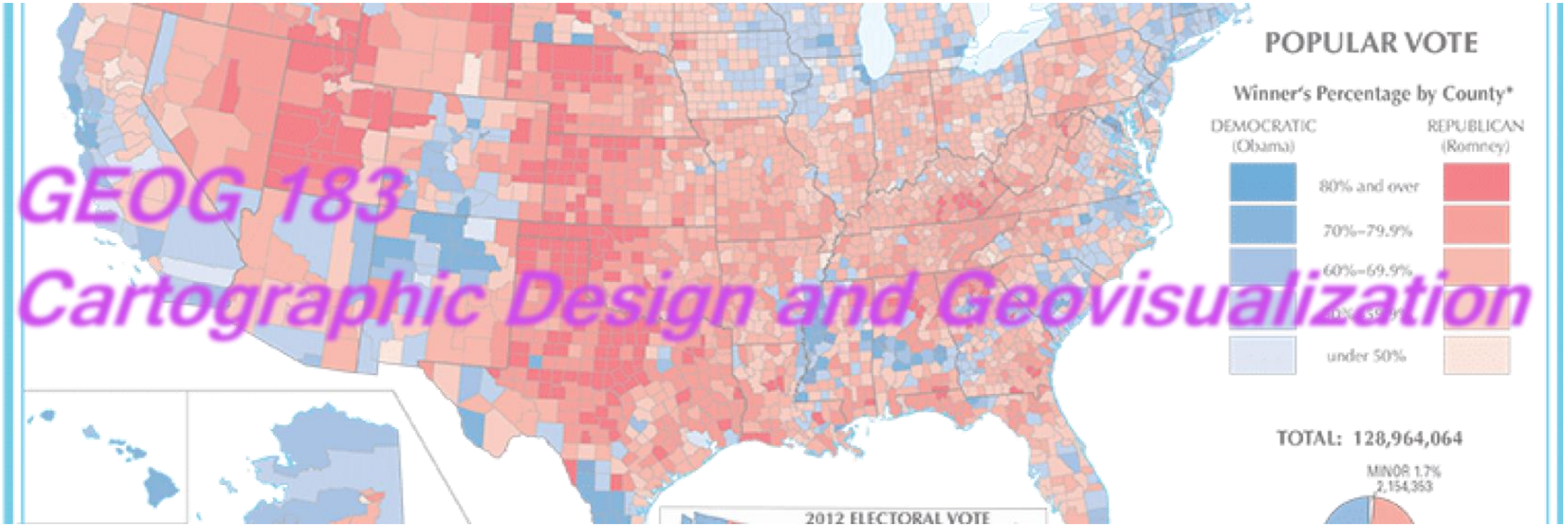


Geog183: Cartographic Design and Geovisualization Spring Quarter 2020

Lecture 15: Dealing with Uncertainty

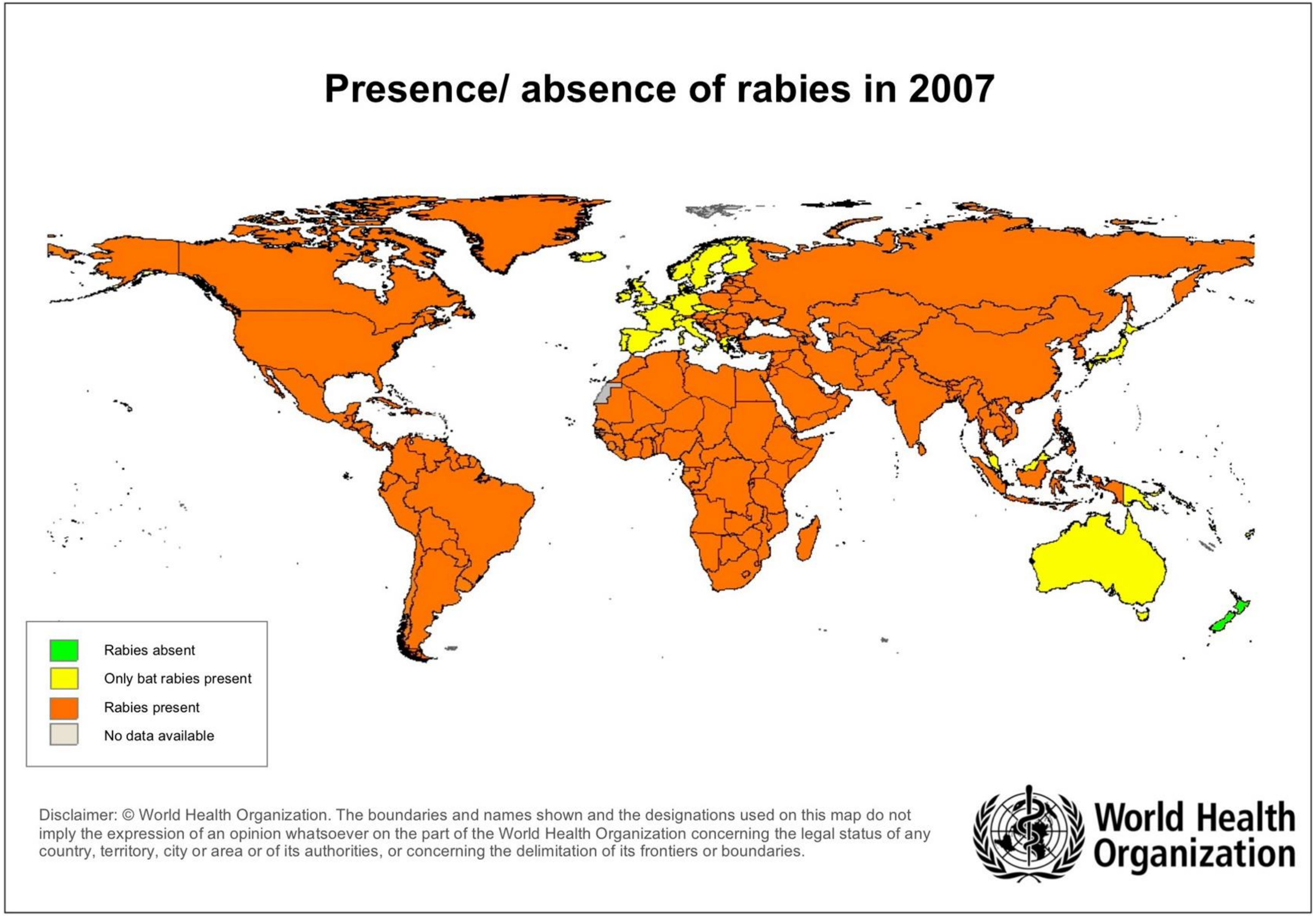
All maps are distortions

- “It’s not easy to lie with maps, it’s essential...to present a useful and truthful picture, an accurate map must tell white lies.” -- *Mark Monmonier*
- “A map is a set of errors that have been agreed upon”
- Distort 3-D world into 2-D abstraction (projection: distorts scale, direction, area, shape)
- Convert real-world features into symbolic objects e.g. city to circle
- Maps can portray abstractions (e.g., gradients, contours) as distinct spatial objects

The limits to mapping

- Measurement errors e.g. sampling, missing data
- Methodological errors e.g. conflation
- Symbology errors
- Map use and interpretation errors
- Misuse, misinterpretation and belief

Attribute uncertainty



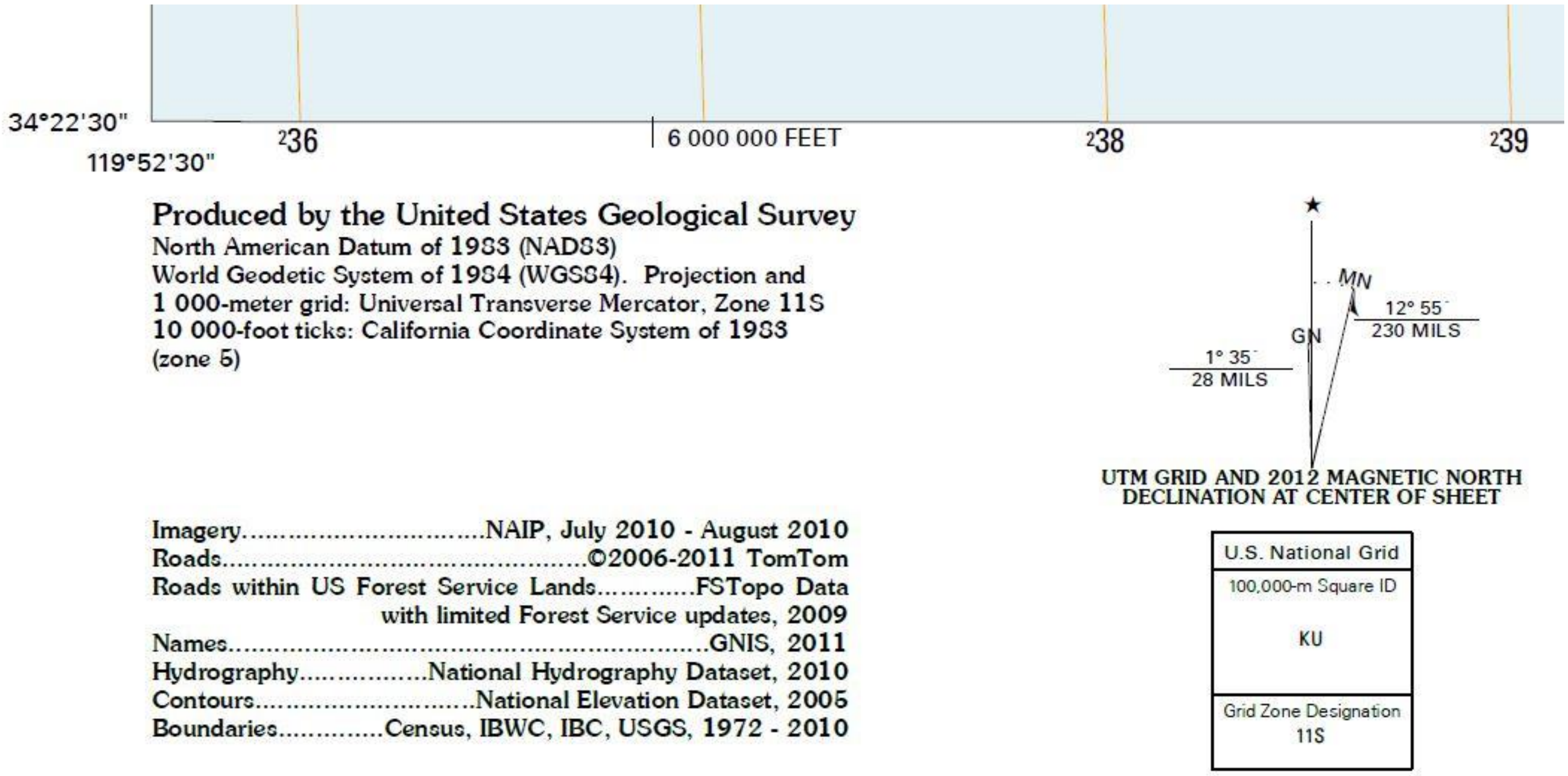
What is Uncertainty?

- NIST data quality:
  - lineage
  - positional accuracy
  - attribute accuracy
  - completeness
  - logical consistency
- Also:
  - source
  - scale
  - methodology
  - Reliability
  - trust and confidence

Example

- 3 reports, two say a bridge exists one says it is destroyed
- Report 3 introduces uncertainty
- Bridge is 0.666 certain, >0.5
- Trust? Reliability of sources
- Method in OSM

Lineage

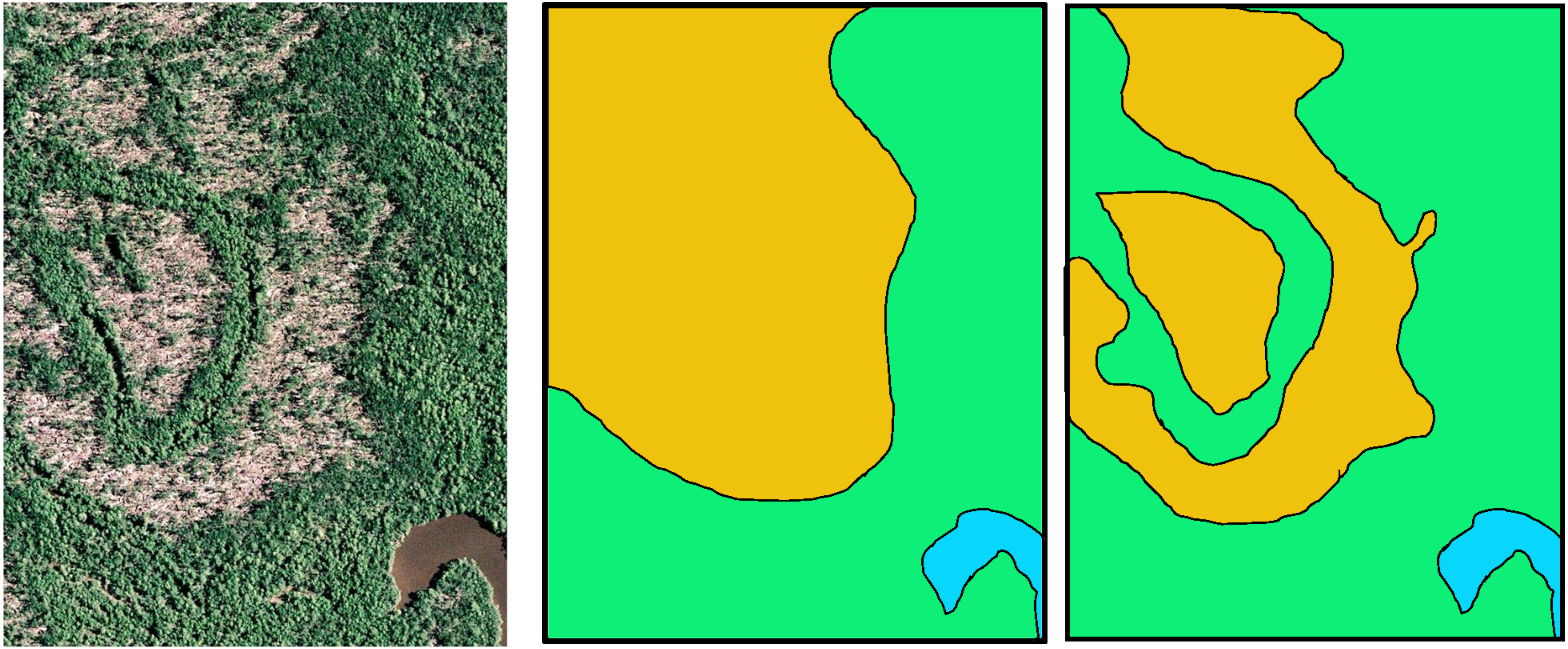

34°22'30"
119°52'30"
236
6 000 000 FEET
238
239
Produced by the United States Geological Survey
North American Datum of 1983 (NAD83)
World Geodetic System of 1984 (WGS84). Projection and
1 000-meter grid: Universal Transverse Mercator, Zone 11S
10 000-foot ticks: California Coordinate System of 1983
(zone 5)
Imagery.....................................NAIP, July 2010 - August 2010
Roads...©2006-2011 TomTom
Roads within US Forest Service Lands.............FSTopo Data
with limited Forest Service updates, 2009
Names...GNIS, 2011
Hydrography..................National Hydrography Dataset, 2010
Contours.............................National Elevation Dataset, 2005
Boundaries..............Census, IBWC, IBC, USGS, 1972 - 2010
MN
12° 55´
230 MILS
GN
1° 35´
28 MILS
UTM GRID AND 2012 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET
U.S. National Grid
100,000-m Square ID
KU
Grid Zone Designation
11S

Positional accuracy e.g. NMAS

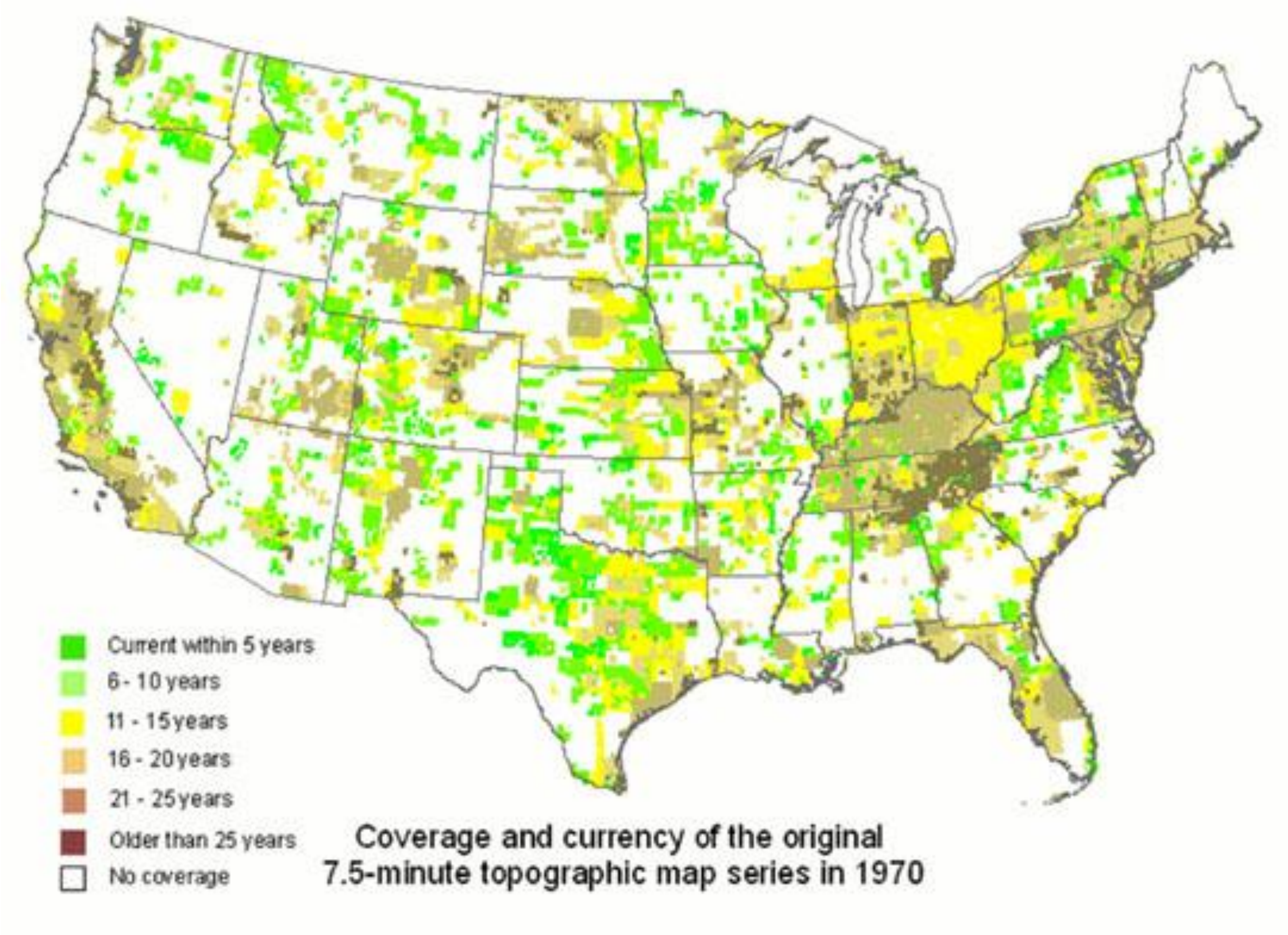
- 1. Horizontal accuracy. For maps on publication scales larger than 1:20,000, not more than 10 percent of the points tested shall be in error by more than 1/30 inch, measured on the publication scale; for maps on publication scales of 1:20,000 or smaller, 1/50 inch. These limits of accuracy shall apply in all cases to positions of well-defined points only. Well-defined points are those that are easily visible or recoverable on the ground, such as the following: monuments or markers, such as bench marks, property boundary monuments; intersections of roads, railroads, etc.; corners of large buildings or structures (or center points of small buildings); etc. In general what is well defined will be determined by what is plotable on the scale of the map within 1/100 inch.
- 2. Vertical accuracy, as applied to contour maps on all publication scales, shall be such that not more than 10 percent of the elevations tested shall be in error more than one-half the contour interval. In checking elevations taken from the map, the apparent vertical error may be decreased by assuming a horizontal displacement within the permissible horizontal error for a map of that scale.
- 3. The accuracy of any map may be tested by comparing the positions of points whose locations or elevations are shown upon it with corresponding positions as determined by surveys of a higher accuracy. Tests shall be made by the producing agency, which shall also determine which of its maps are to be tested, and the extent of the testing.
- 4. Published maps meeting these accuracy requirements shall note this fact on their legends, as follows: “This map complies with National Map accuracy Standards.”
- 5. Published maps whose errors exceed those aforestated shall omit from their legends all mention of standard accuracy.
- 6. When a published map is a considerable enlargement of a map drawing (manuscript) or of a published map, that fact shall be stated in the legend. For example, “This map is an enlargement of a 1:20,000-scale map drawing,” or “This map is an enlargement of a 1:24,000-scale published map.”
- 7. To facilitate ready interchange and use of basic information for map construction among all Federal mapmaking agencies, manuscript maps and published maps, wherever economically feasible and consistent with the uses to which the map is to be put, shall conform to latitude and longitude boundaries, being 15 minutes of latitude and longitude, or 7.5 minutes, or 3-3/4 minutes in size.

Issued June 10, 194l U.S. BUREAU OF THE BUDGET
Revised April 26, 1943
Revised June 17, 1947

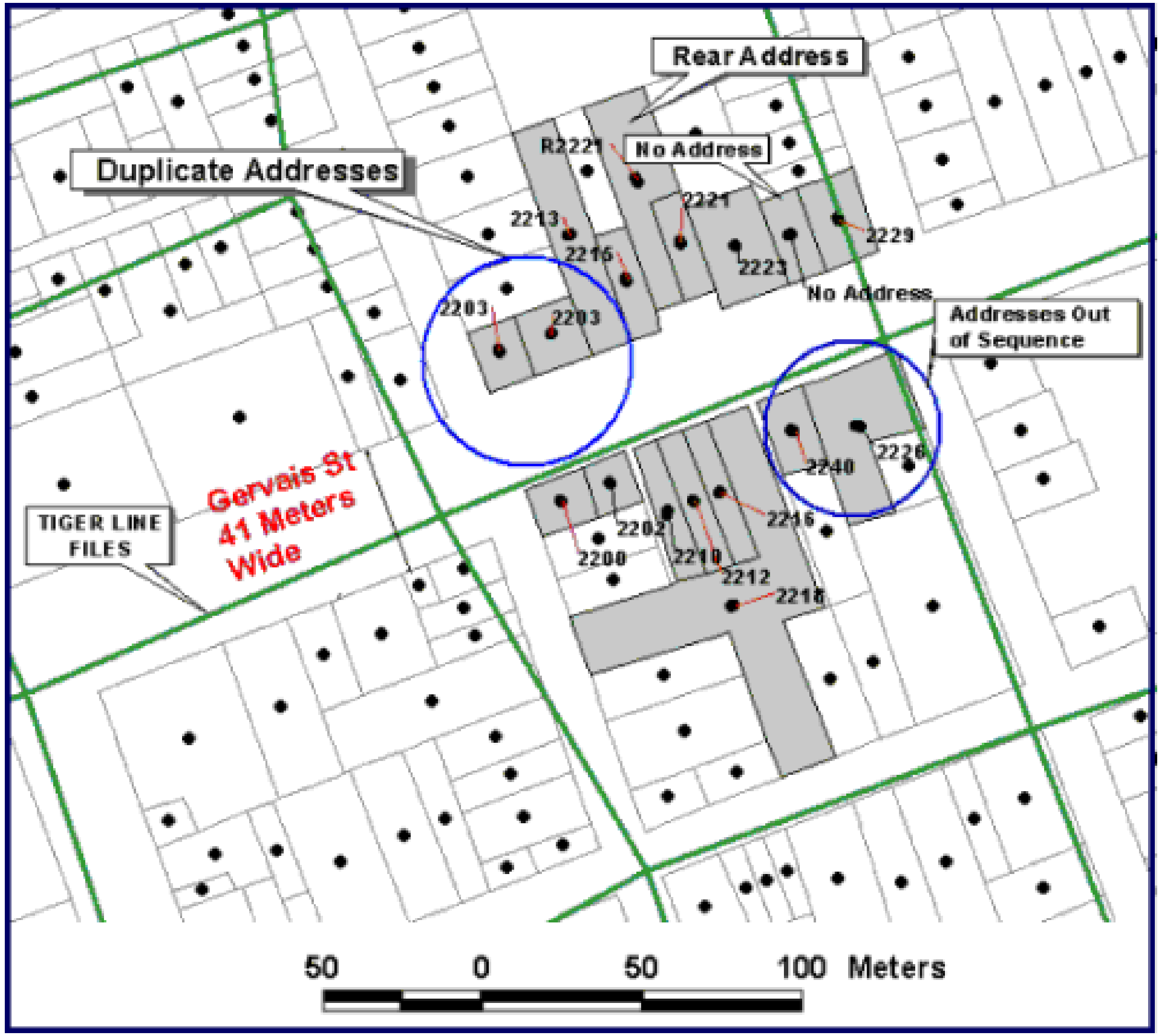
Attribute accuracy/definition and scale

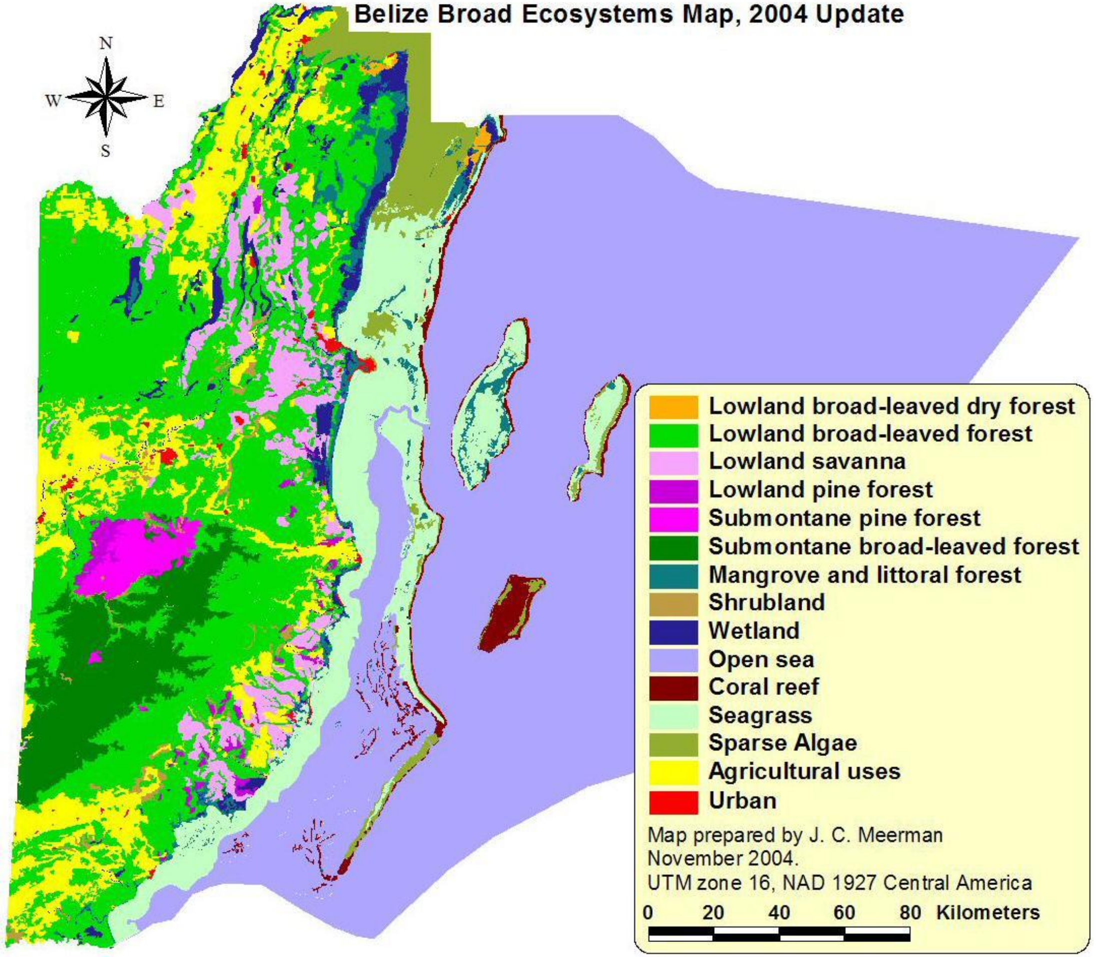


Temporal and differential completeness



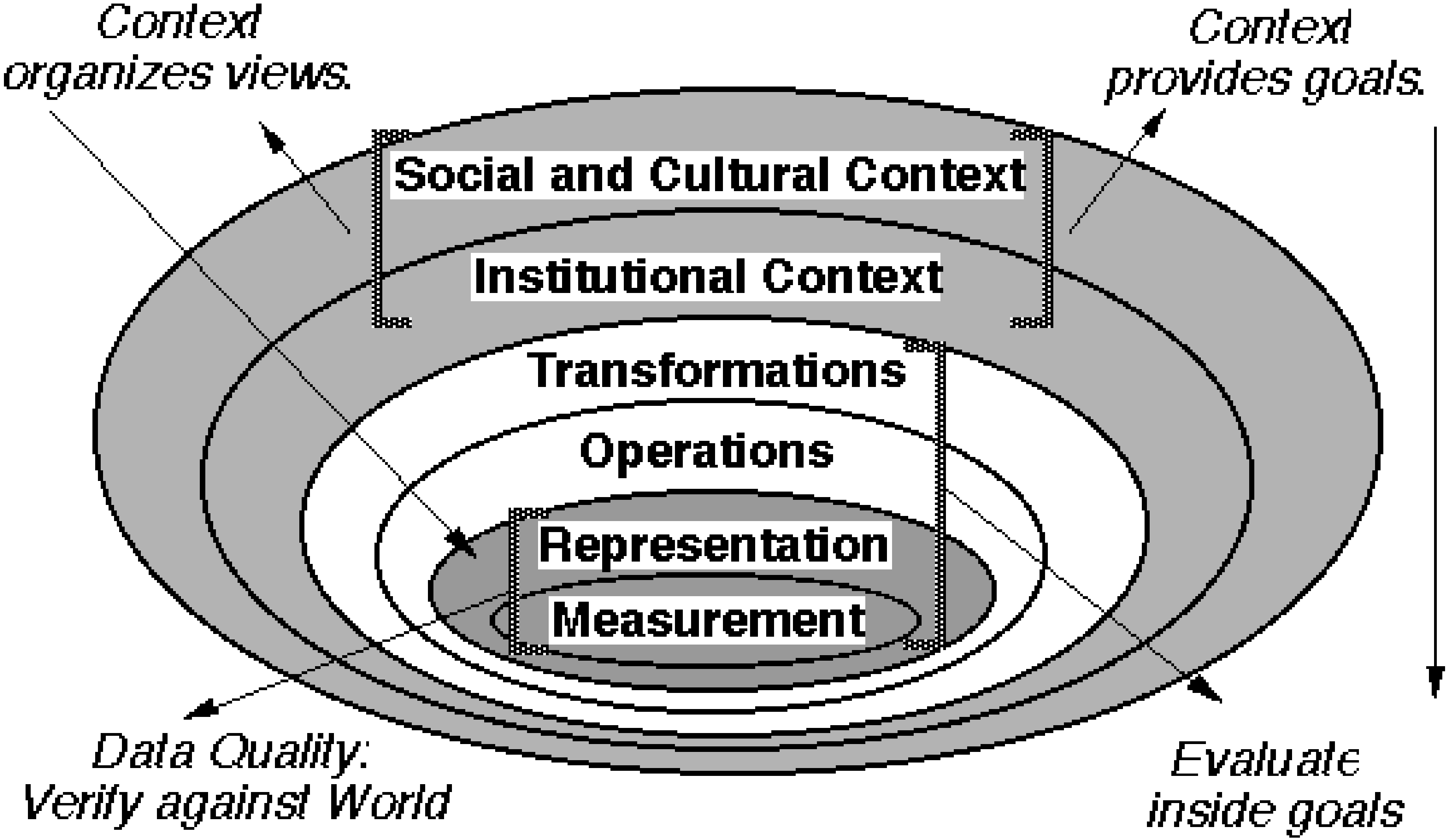
Logical completeness

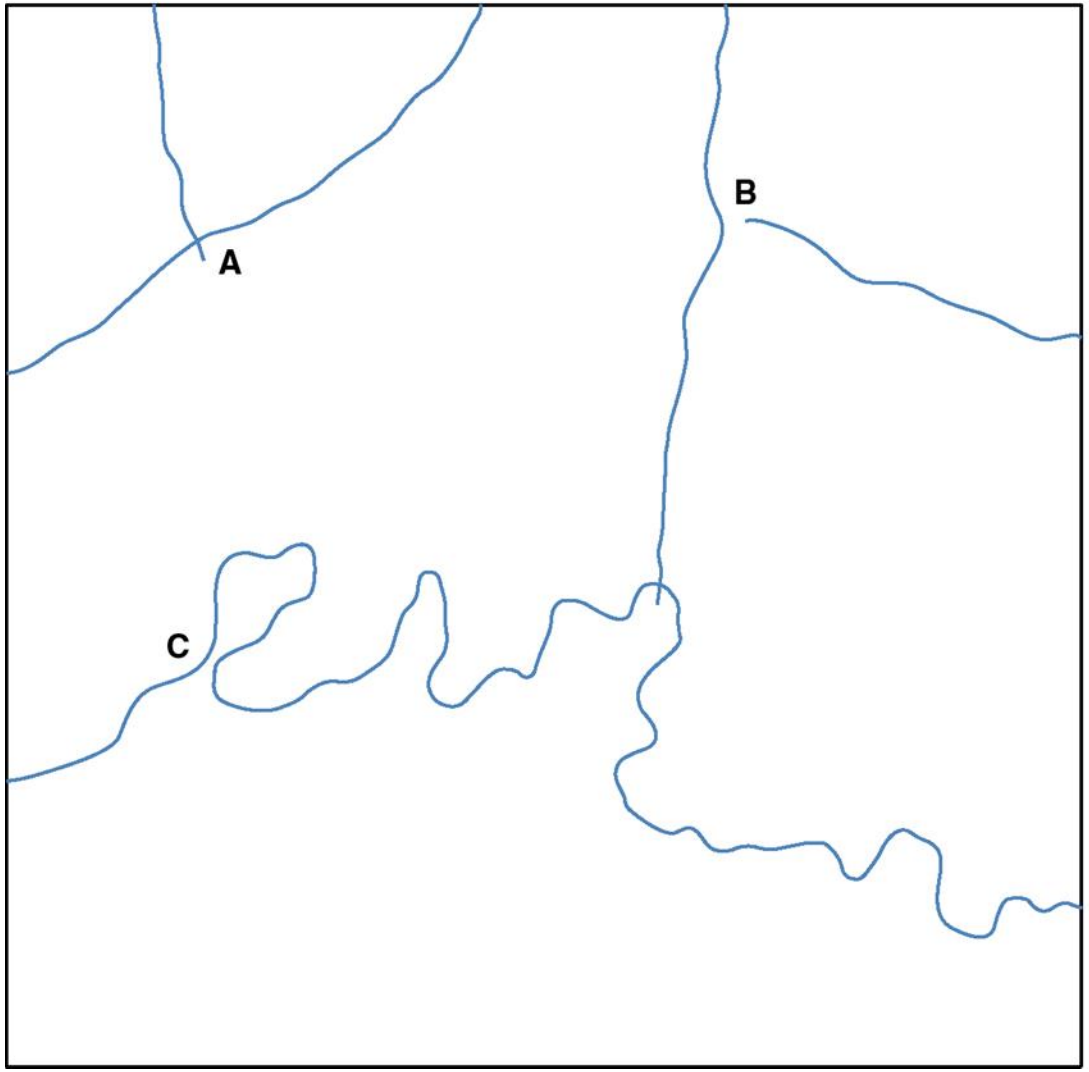




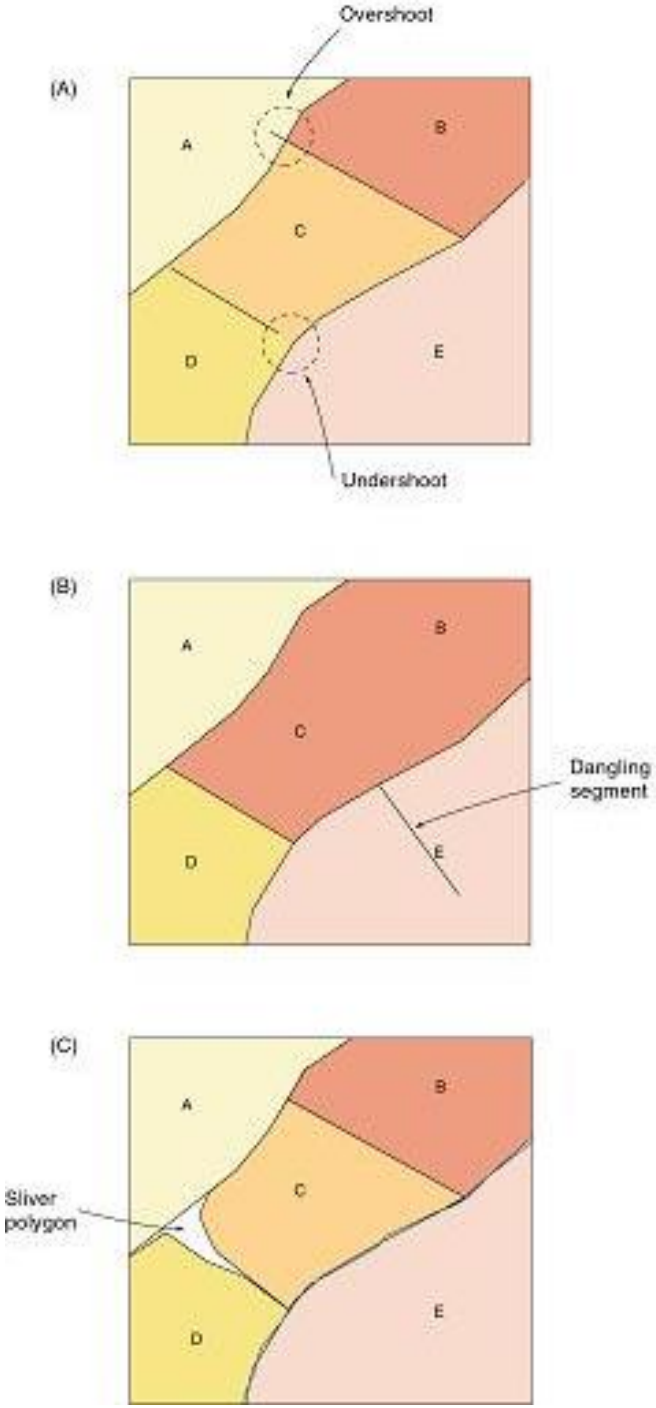
Nick Chrisman's View

(www.wiley.com/college/chrisman/define.html)

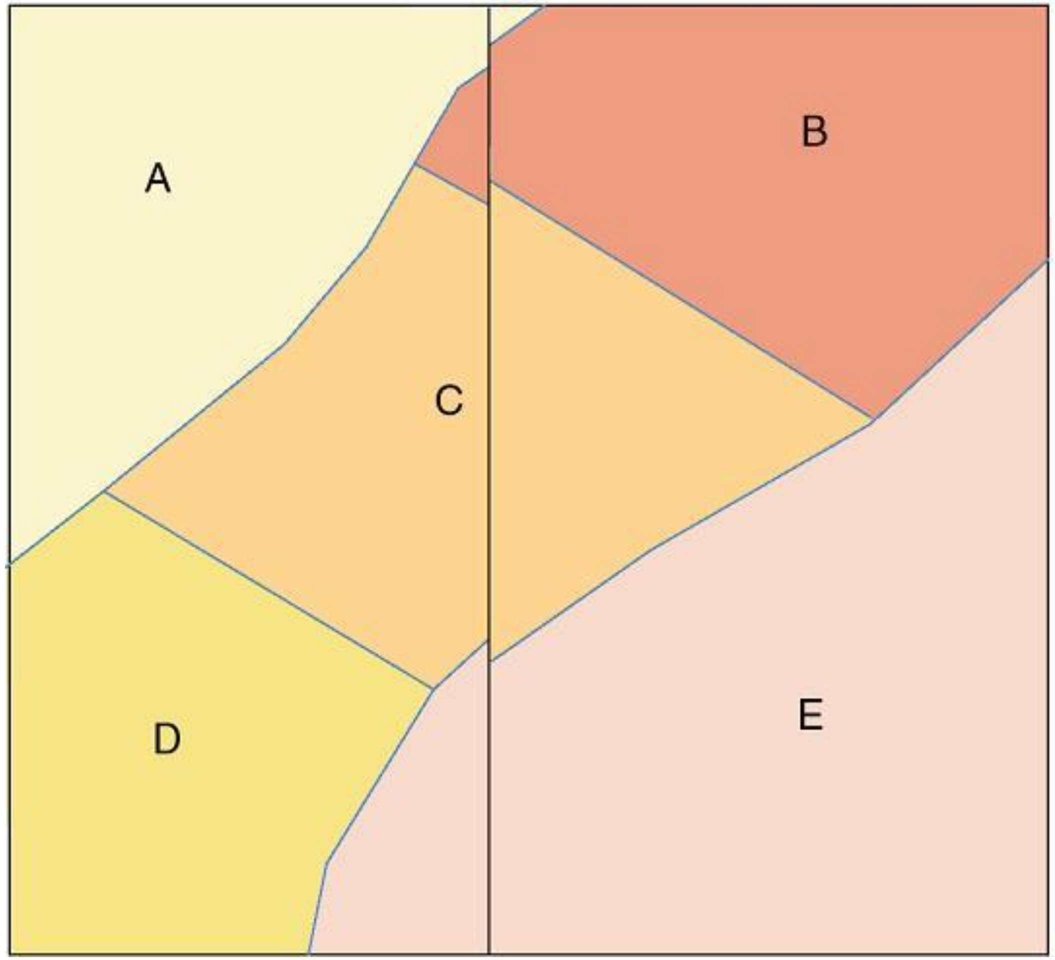


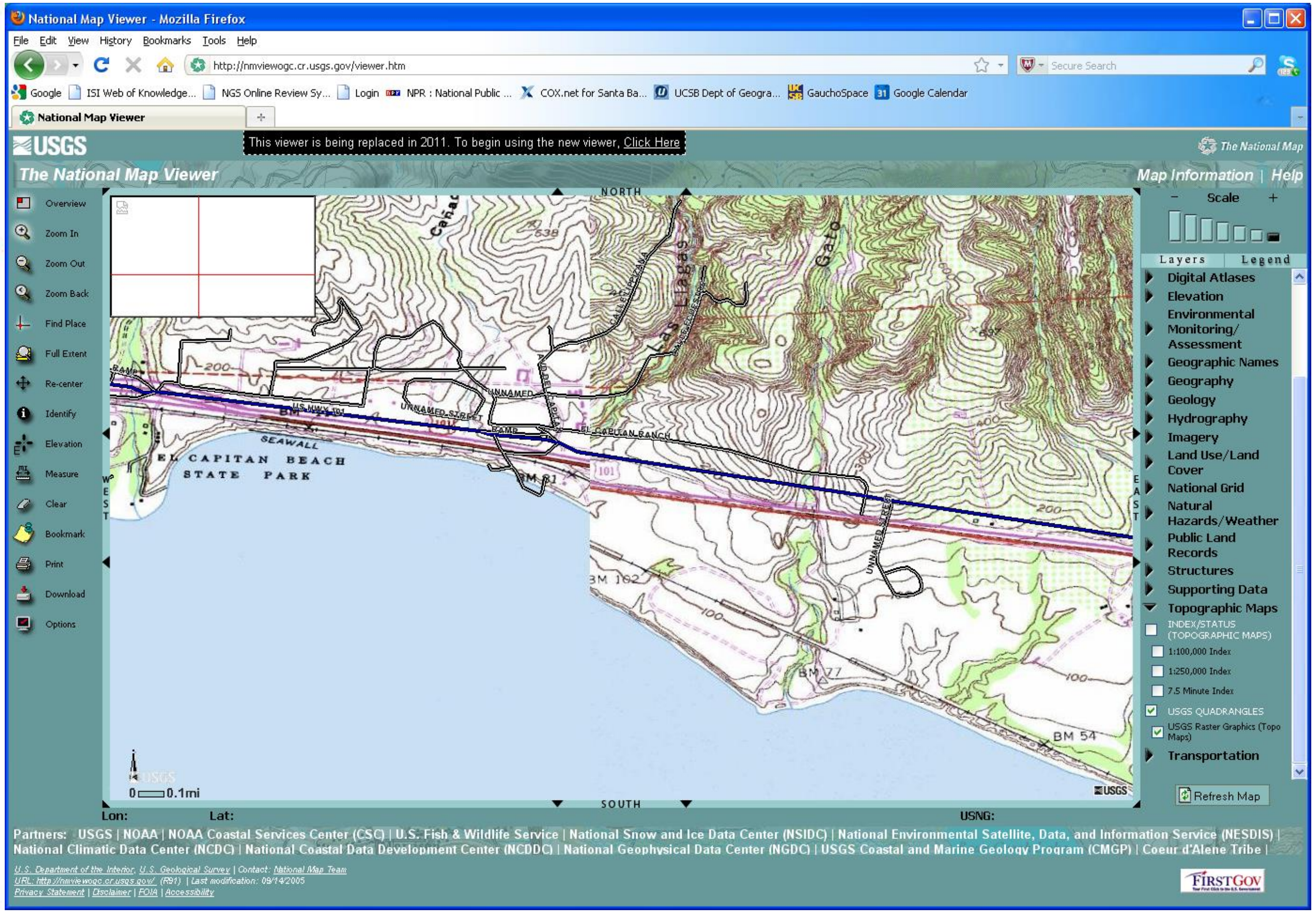


Source: Longley et al.



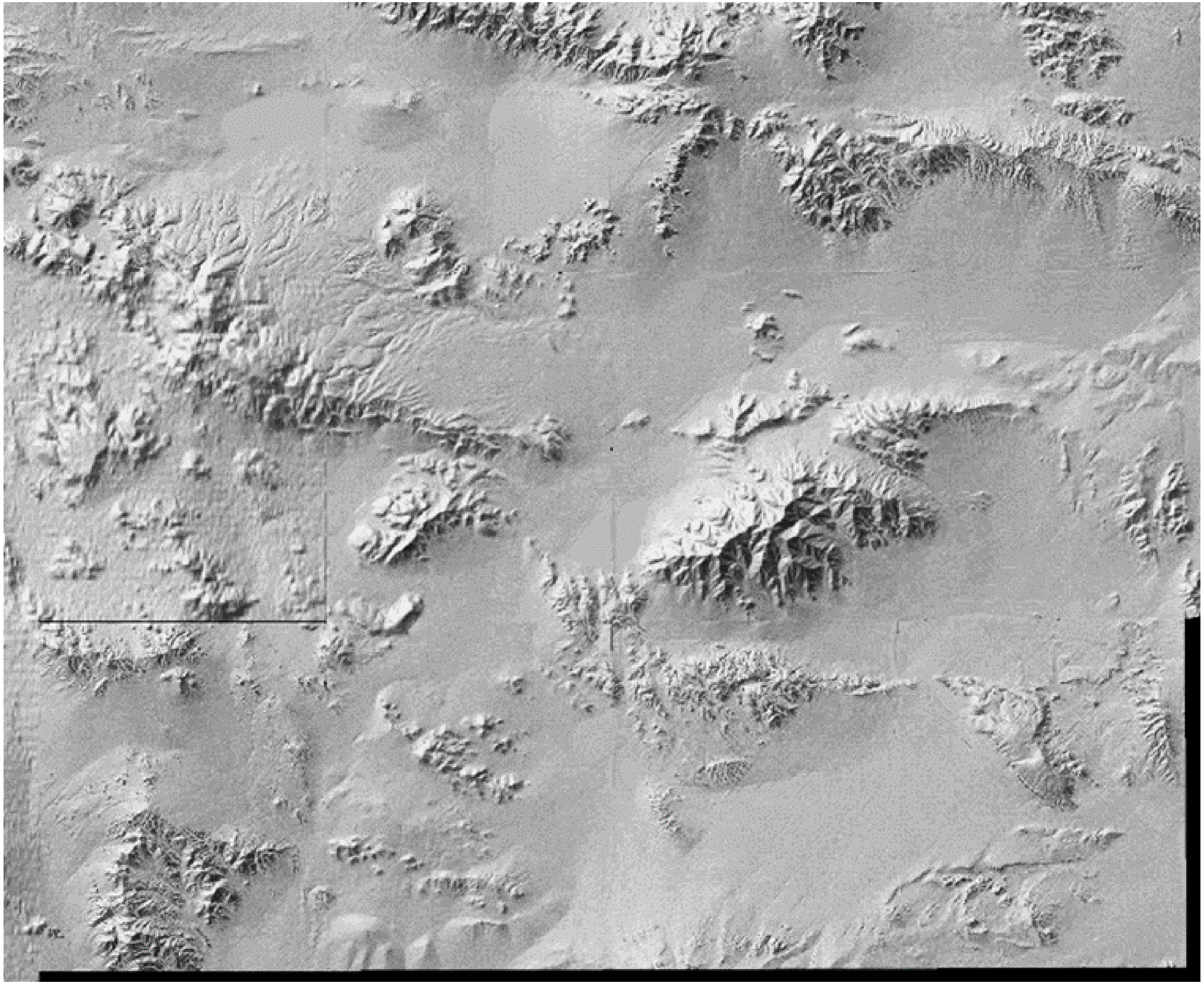
Tile/Merge



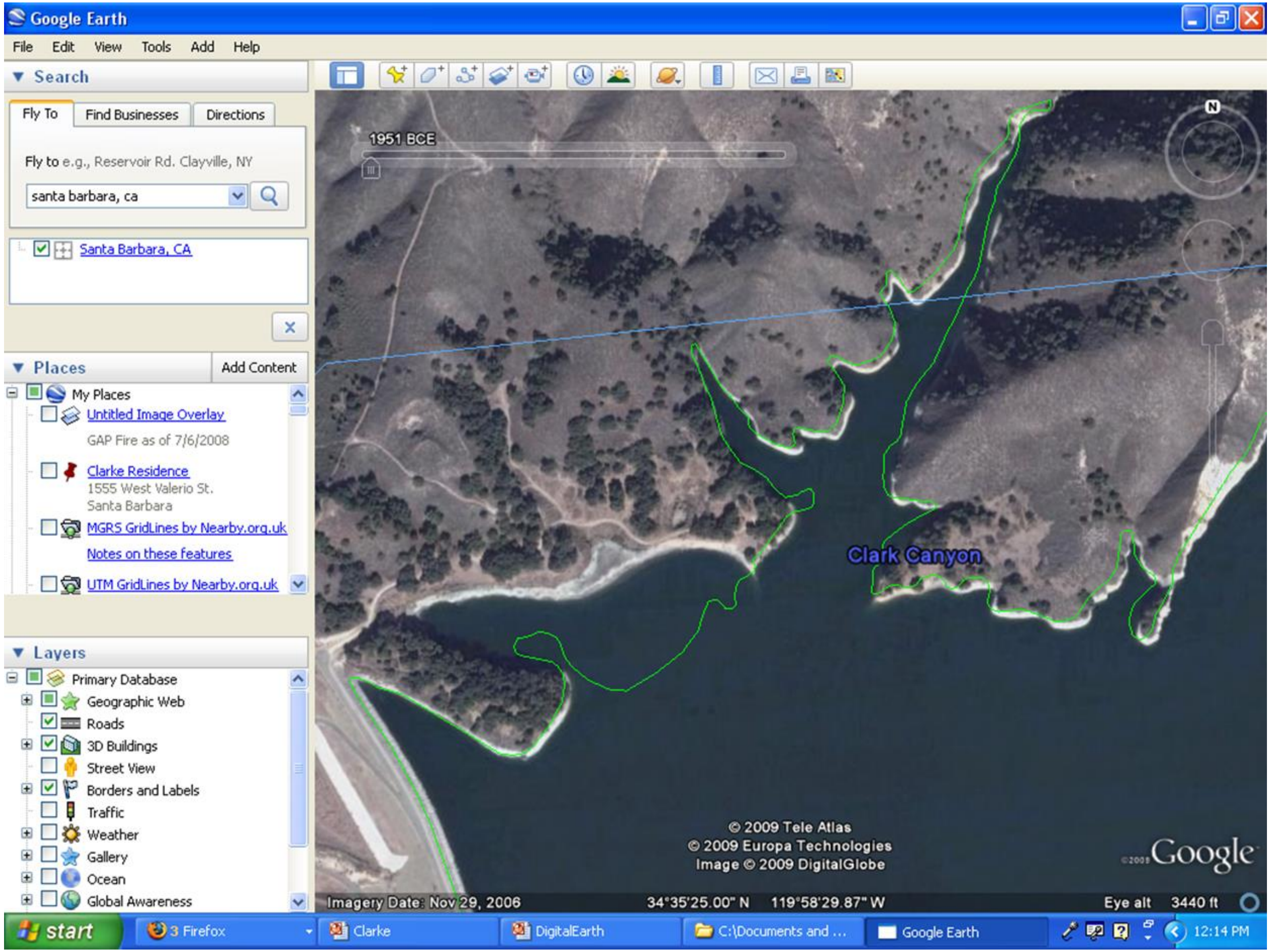


Source: Longley et al.

Spot the tiles



Scale-induced, temporal error



1994


2015
Bradbury Dam
Image U.S. Geological Survey
Imagery Date: 5/31/1994
34°35'48.94" N 119°59'32.34" W elev


Bradbury Dam
© 2016 Google

2015

Generalization uncertainty

- Measurements not perfectly accurate
- Maps distorted when generalized
  - Selection
  - Simplification
  - Combination
  - Displacement
- Objects at scale can be far less than 0.1mm
- Definitions vague, ambiguous, subjective
- Landscape has changed over time

Classification inconsistency

NLCD 1992 Land Cover Classification Legend

- 11 Open Water
- 12 Perennial Ice/Snow
- 21 Low Intensity Residential
- 22 High Intensity Residential
- 23 Commercial/Industrial/Transportation
- 31 Bare Rock/Sand/Clay
- 32 Quarries/Strip Mines/Gravel Pits
- 33 Transitional Barren
- 41 Deciduous Forest
- 42 Evergreen Forest
- 43 Mixed Forest
- 51 Shrubland
- 61 Orchards/Vineyards/Other
- 71 Grassland/Herbaceous
- 81 Pasture/Hay
- 82 Row Crops
- 83 Small Grains
- 84 Fallow
- 85 Urban/Recreational Grasses
- 91 Woody Wetlands
- 92 Emergent Herbaceous Wetlands

ARTIFICIAL SURFACES

URBAN FABRIC
- 111 Continuous urban fabric
- 112 Discontinuous urban fabric

INDUSTRIAL, COMMERCIAL AND TRANSPORT UNITS
- 121 Industrial, commercial and public units
- 122 Road and rail networks and associated land
- 123 Port areas
- 124 Airport

MINES, DUMPS AND CONSTRUCTION SITES
- 131 Mineral extraction sites
- 132 Dump sites
- 133 Construction sites

ARTIFICIAL NON-AGRICULTURAL VEGETATED AREAS
- 141 Green urban areas
- 142 Sport and leisure facilities

AGRICULTURAL AREAS

ARABLE LAND
- 211 Non-irrigated arable land

PERMANENT CROPS
- 221 Vineyards
- 222 Fruit trees and berries plantations

PASTURES
- 231 Pastures

HETEROGENEOUS AGRICULTURAL AREAS
- 242 Complex cultivation patterns
- 243 Land principally occupied by agriculture, with significant areas of natural vegetation

FOREST AND SEMINATURAL AREA

FORESTS
- 311 Broad-leaved forest
- 312 Coniferous forest
- 313 Mixed forest

SCRUBS AND/OR HERBACEOUS VEGETATION
- 321 Natural grassland
- 322 Moors and heathland
- 324 Transitional woodland-scrub

OPEN SPACES WITH LITTLE OR NO VEGETATION
- 331 Beaches, dunes, sand
- 332 Bare rock
- 333 Sparsely vegetated areas
- 334 Burnt areas
- 335 Glaciers and perpetual snow

WETLANDS

INLAND WETLANDS
- 411 Inland marshes
- 412 Peat bogs

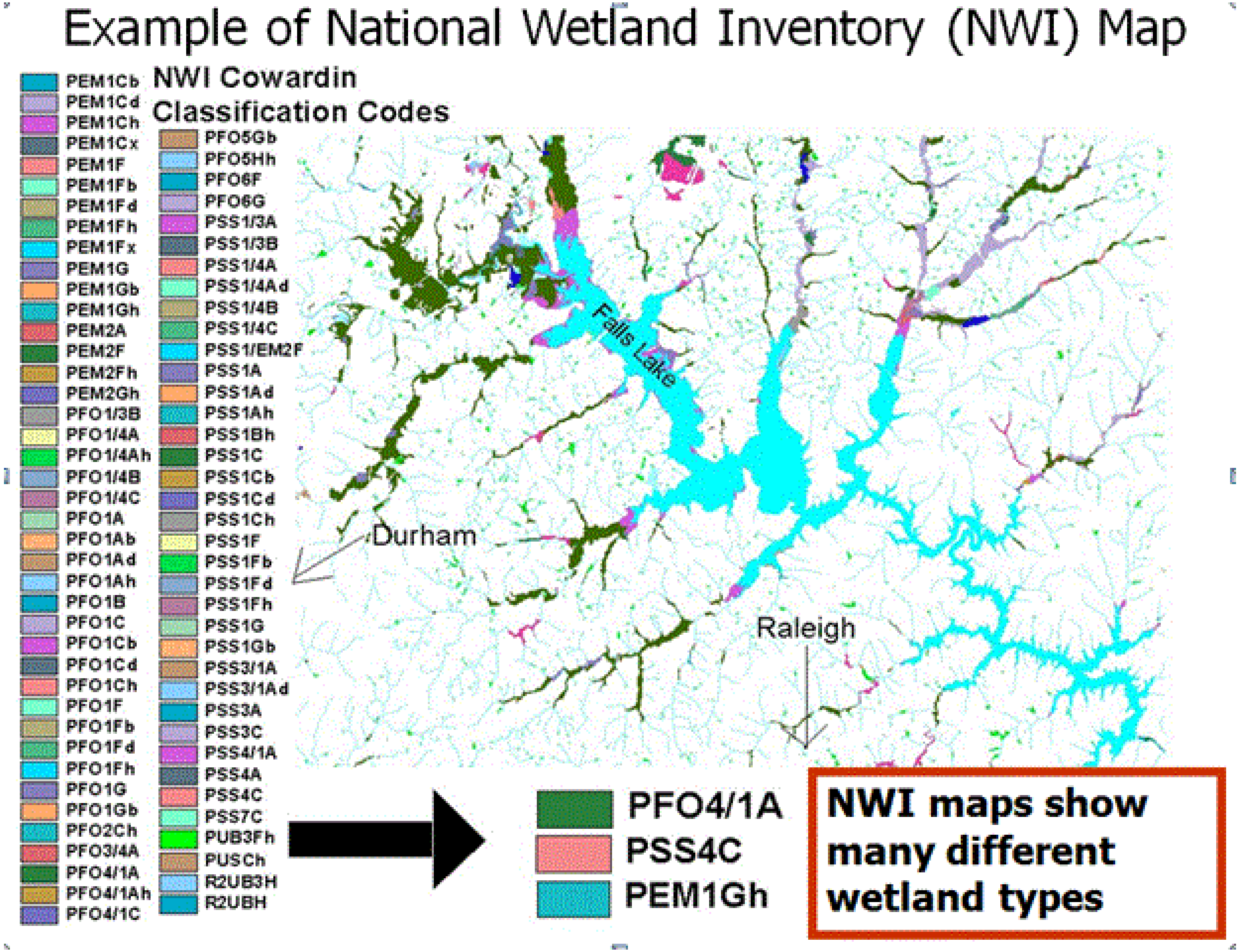
COASTAL WETLANDS
- 421 Salt marshes
- 423 Intertidal flats

WATER BODIES

INLAND WATERS
- 511 Water courses
- 512 Water bodies

MARINE WATERS
- 521 Coastal lagoons
- 522 Estuaries
- 523 Sea and ocean

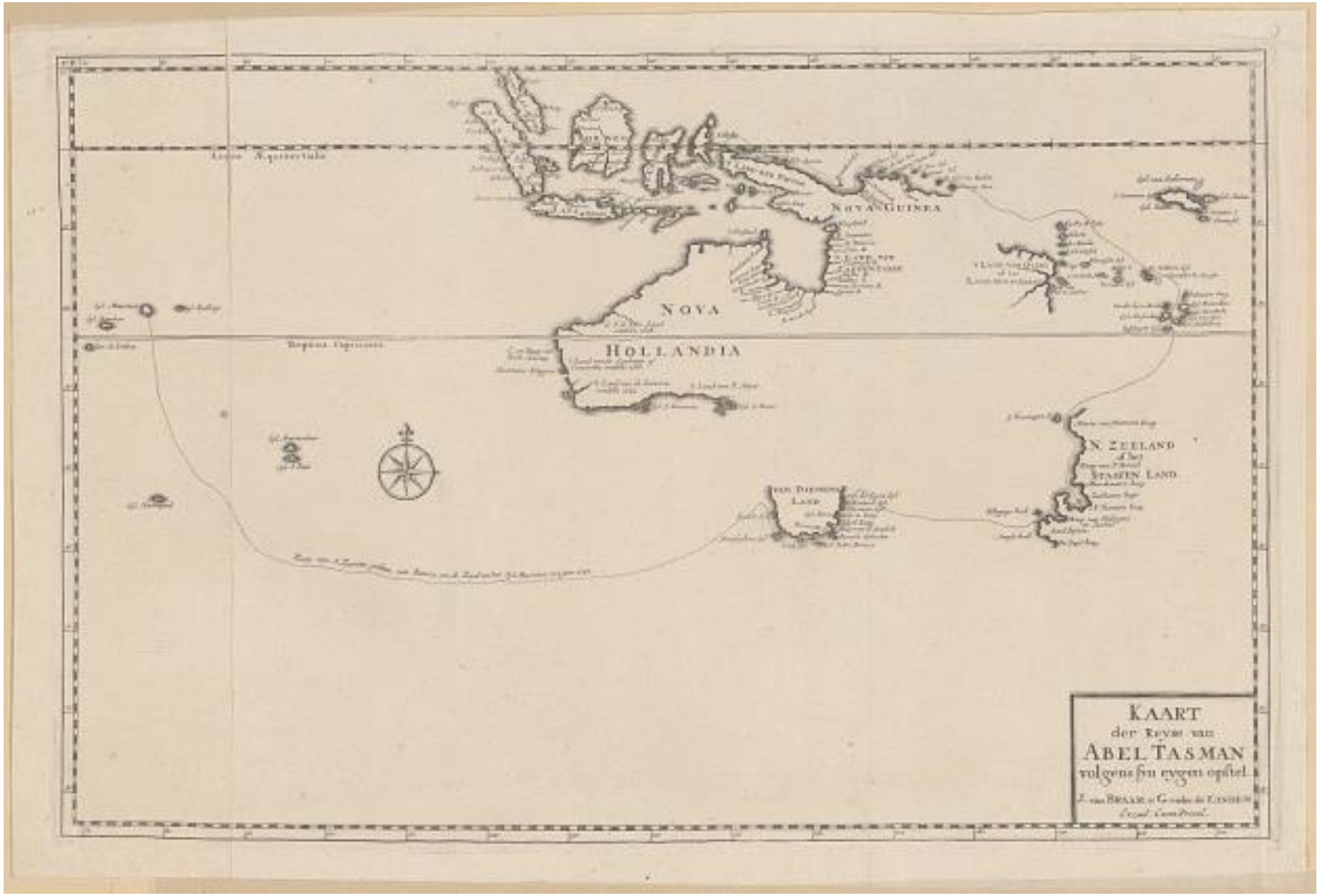
Classification purpose



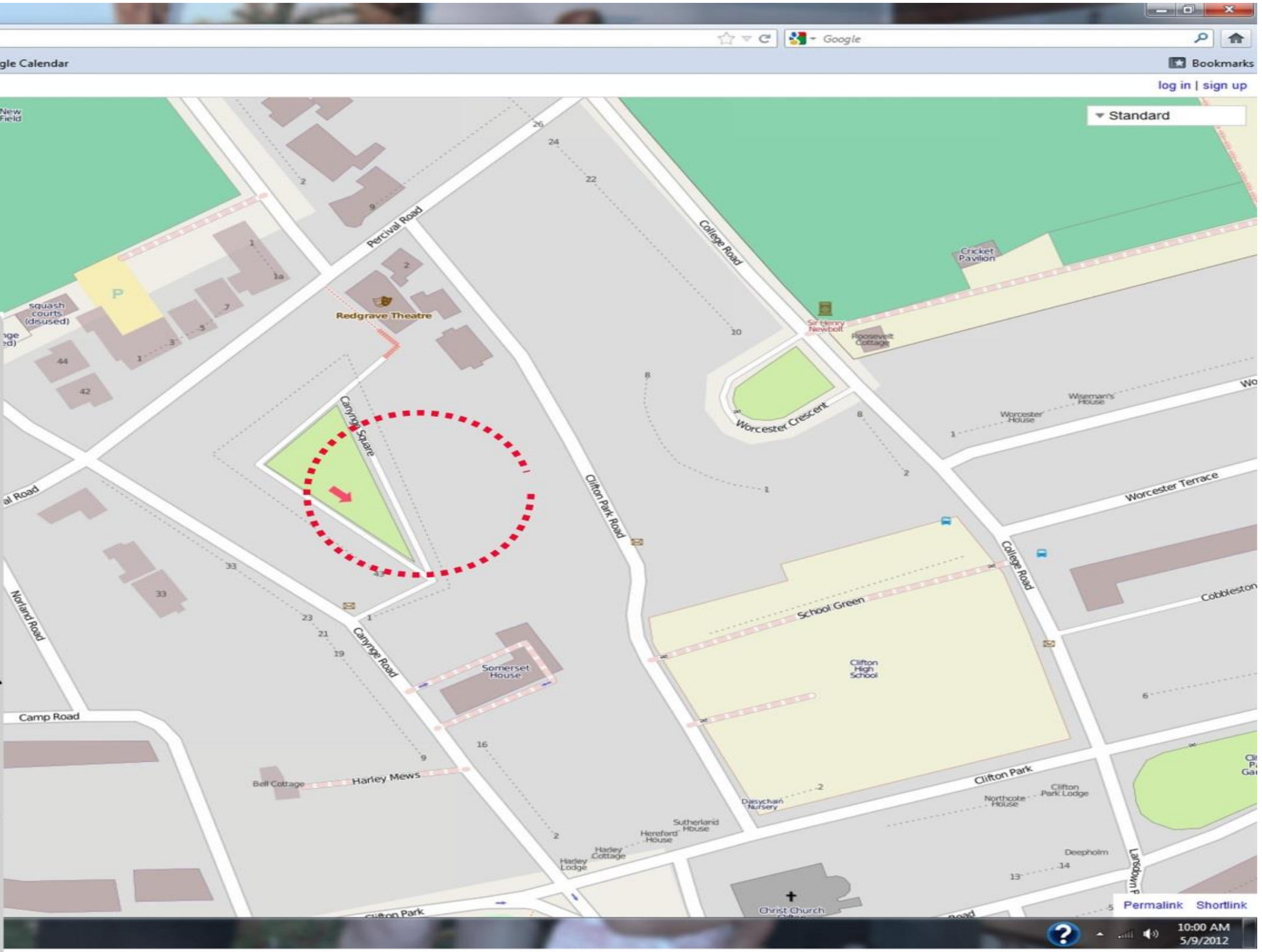
Dealing with uncertainty

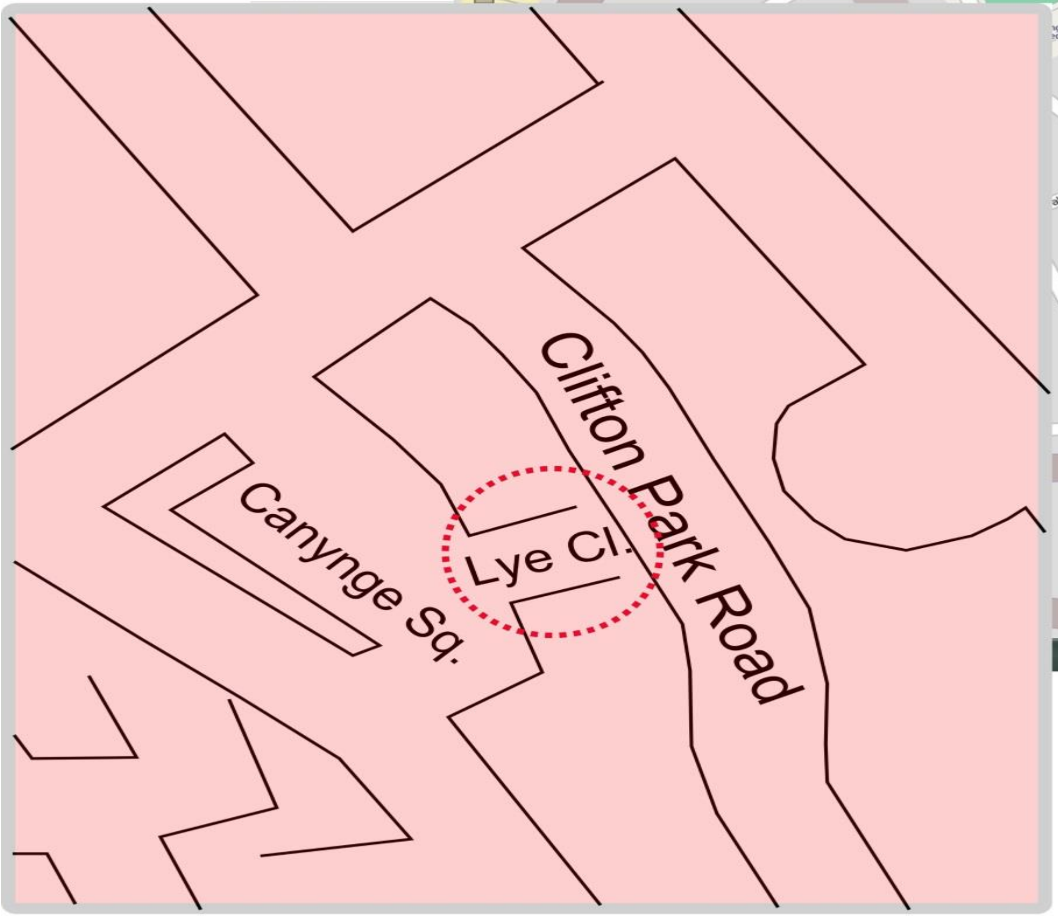
- Simple quantification
- Showing missing data
- Conflation
- Symbolizing uncertainty

Map showing the discoveries of Abel Tasman in 1642-43 and 1644. The map includes the track of Tasman’s first voyage 1642-43 from Mauritius. It was included in Vol. 3, part 2 of his Francois Valentijn’s history, Oud en nieuw Oost-Indien (Old and new East Indies).



A Cartographic Trap





Left: From A-Z streetmap of central Bristol (redrafted).
Above: Open Street Map

Occasionally TIGER Data are Inaccurate or Imprecise

Quantification

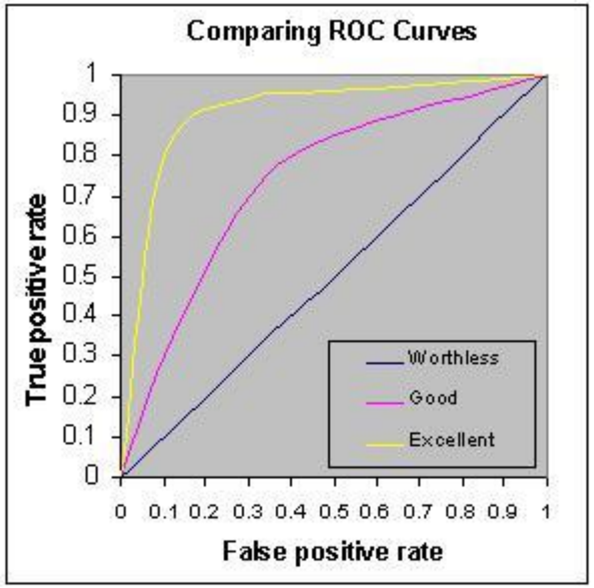
- Horizontal and vertical RMSE
- Recognized by GPS as DOP
- Categorical: by Confusion matrix, User/Producer, Kappa, ROC

Root Mean Squared Error

$$RMS = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(y_i - \hat{y}_i\right)^2} = \sqrt{\frac{1}{n}\sum_{i=1}^{n} e_i^2}$$

$$RMS = \sqrt{MSE}$$

		prediction outcome		
		p	n	total
actual value	p'	True Positive	False Negative	P'
	n'	False Positive	True Negative	N'
	total	P	N	

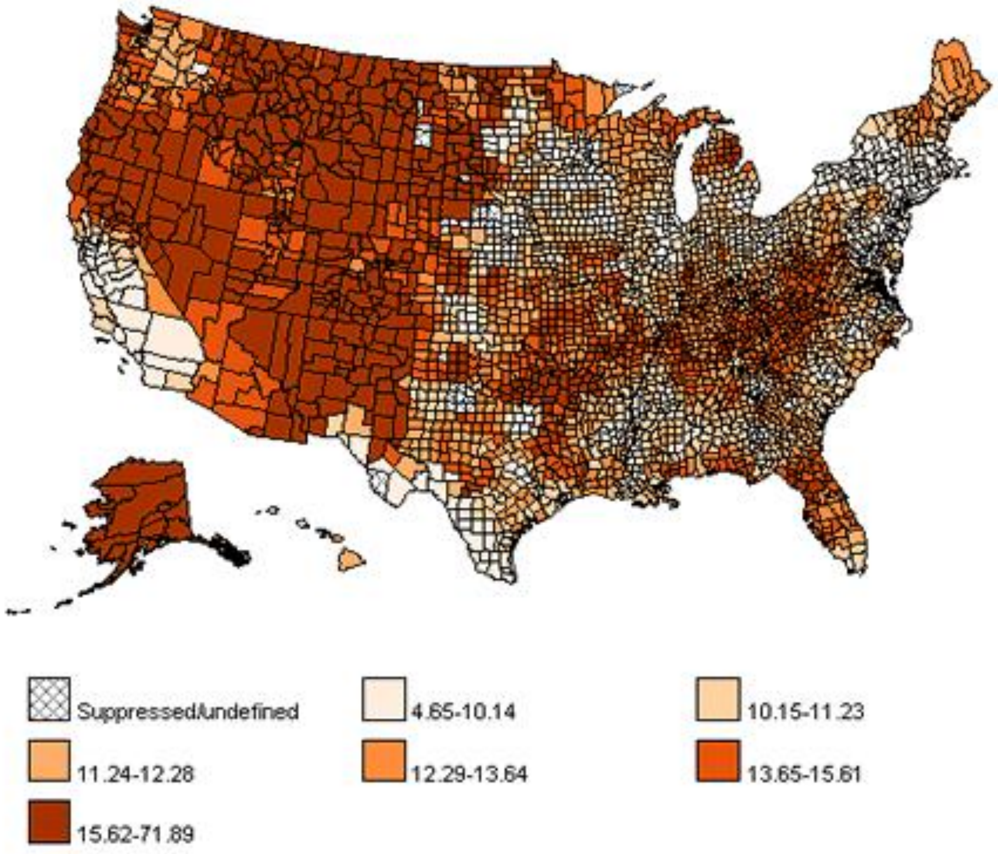


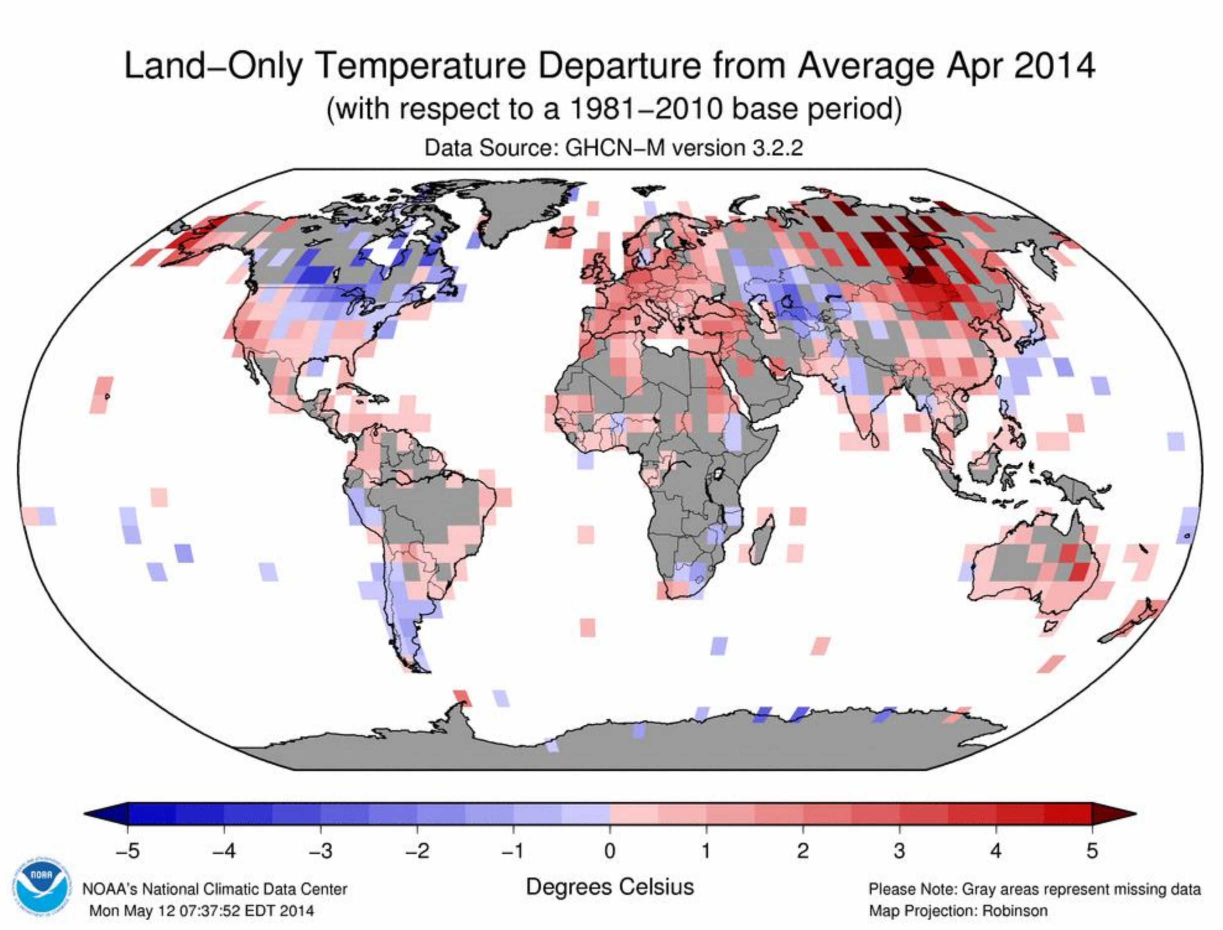
Classified Data	Samples in Test Area B: Water body [L1]	Built up [L1]	Local play area [L1]	Tree area [L1]	Grass land[L1]	Shrub & mix [L1]	Total	User's Accuracy
Water body[L1]	**18**	0	0	0	0	0	18	100.0%
Built up [L1]	20	**50**	2	1	4	18	95	100.0%
Local Play area [L1]	0	0	**4**	0	1	0	5	80.0%
Tree area [L1]	2	0	0	**19**	0	3	24	79.2%
Grass land [L1]	0	0	0	0	**38**	0	38	100.0%
Shrub & mix [L1]	10	0	0	30	7	**29**	76	58.0%
Total	50	50	6	50	50	50		
Producer's Accuracy	36.0%	100.0%	66.7%	38.0%	76.0%	58.0%		
KIA Per Class	31.2%	100.0%	66.0%	31.6%	71.8%	40.3%		

Overall Classification Accuracy = 61.7% Kappa statistic = 52.6%

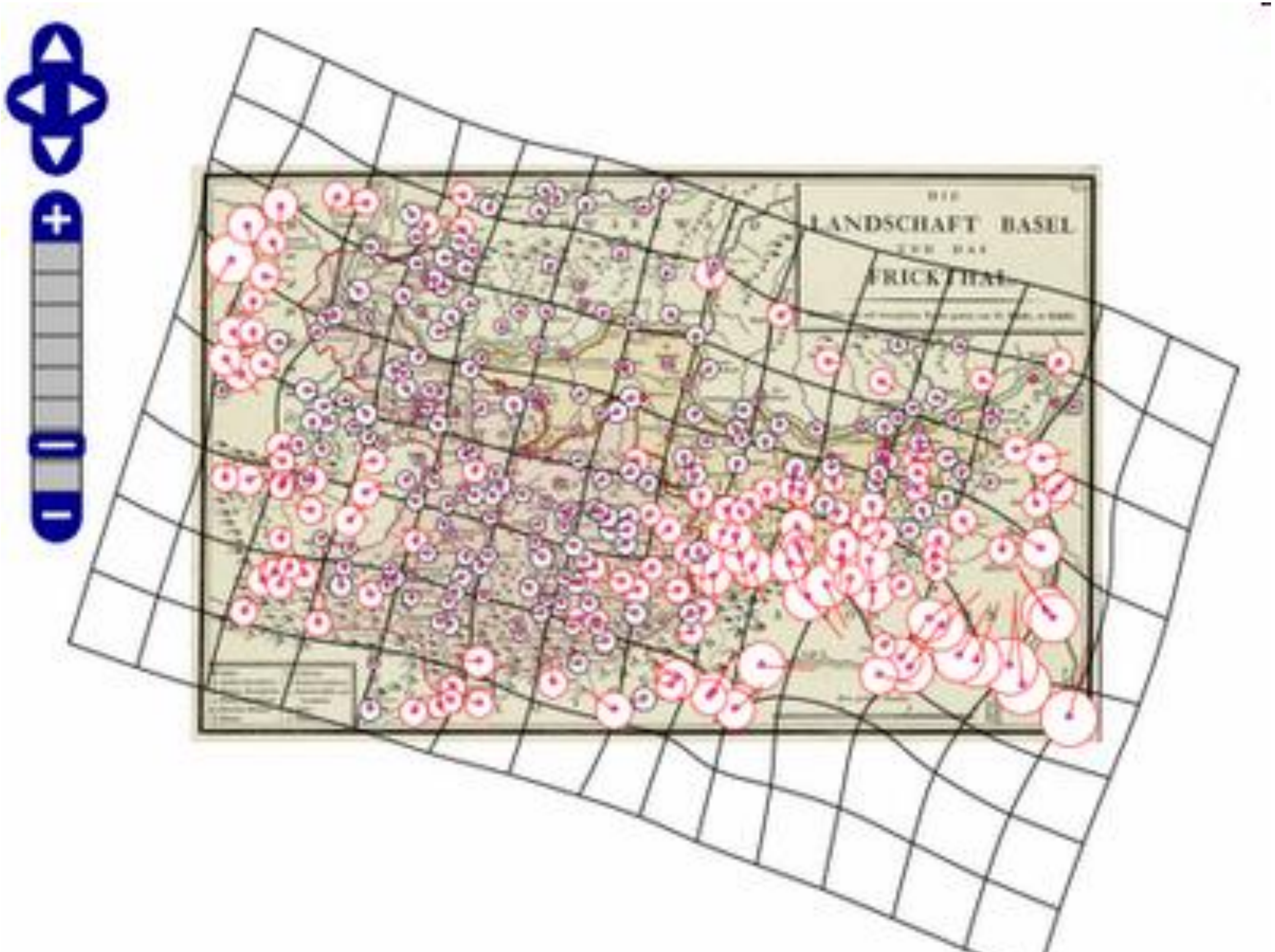
Missing data

Age-adjusted suicide rates 200-206 per 100,000

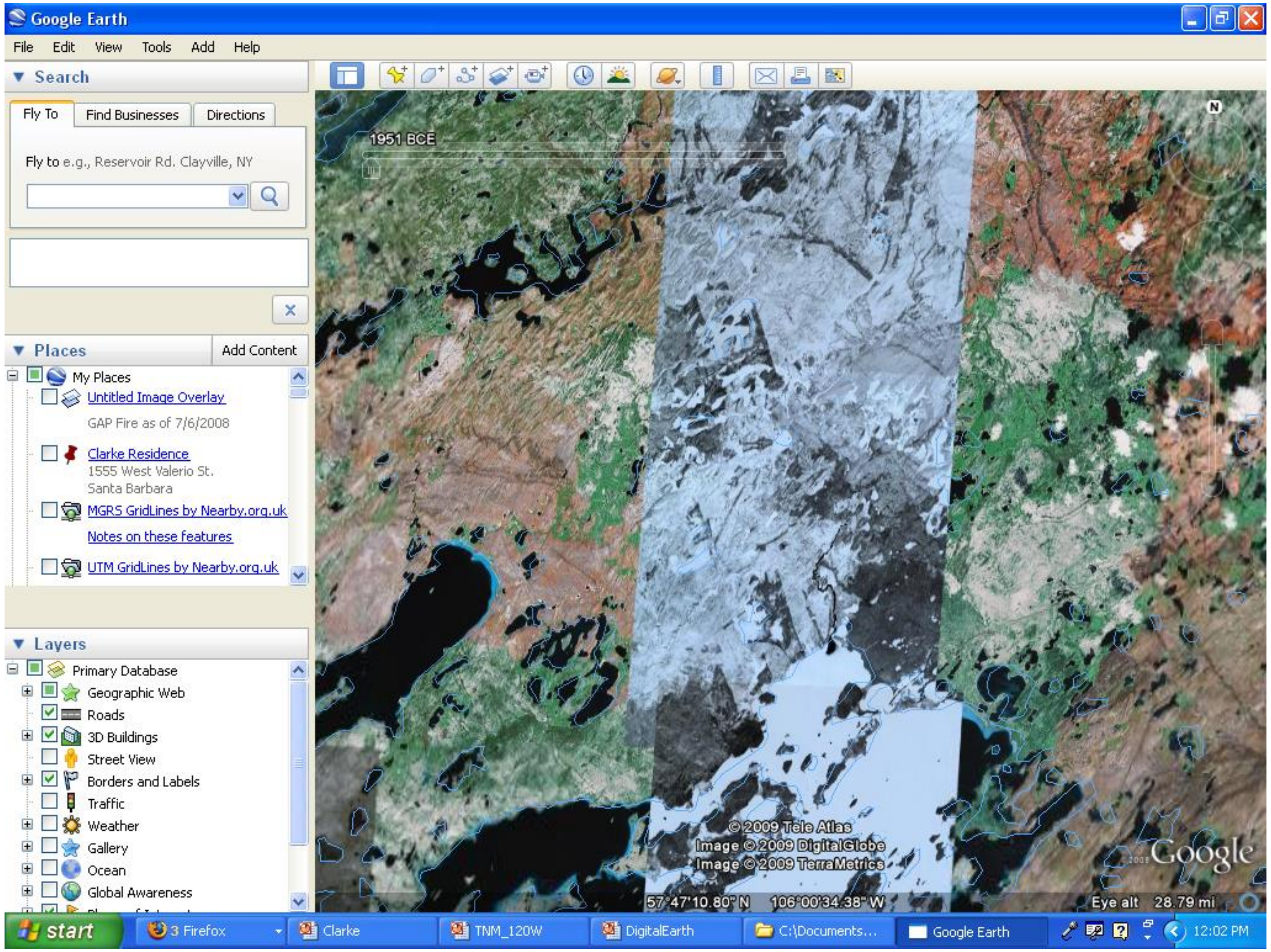


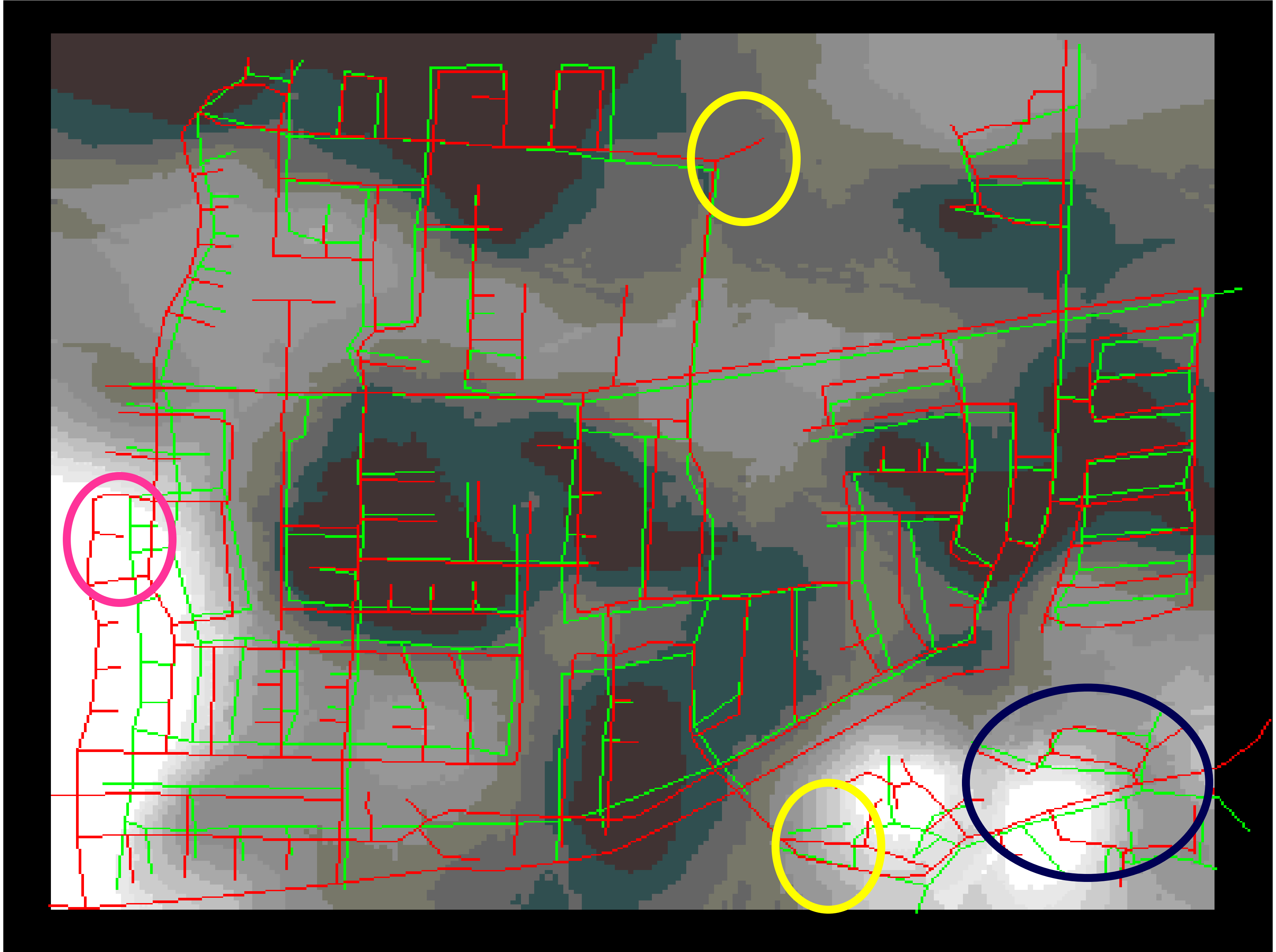


Rubber sheeting



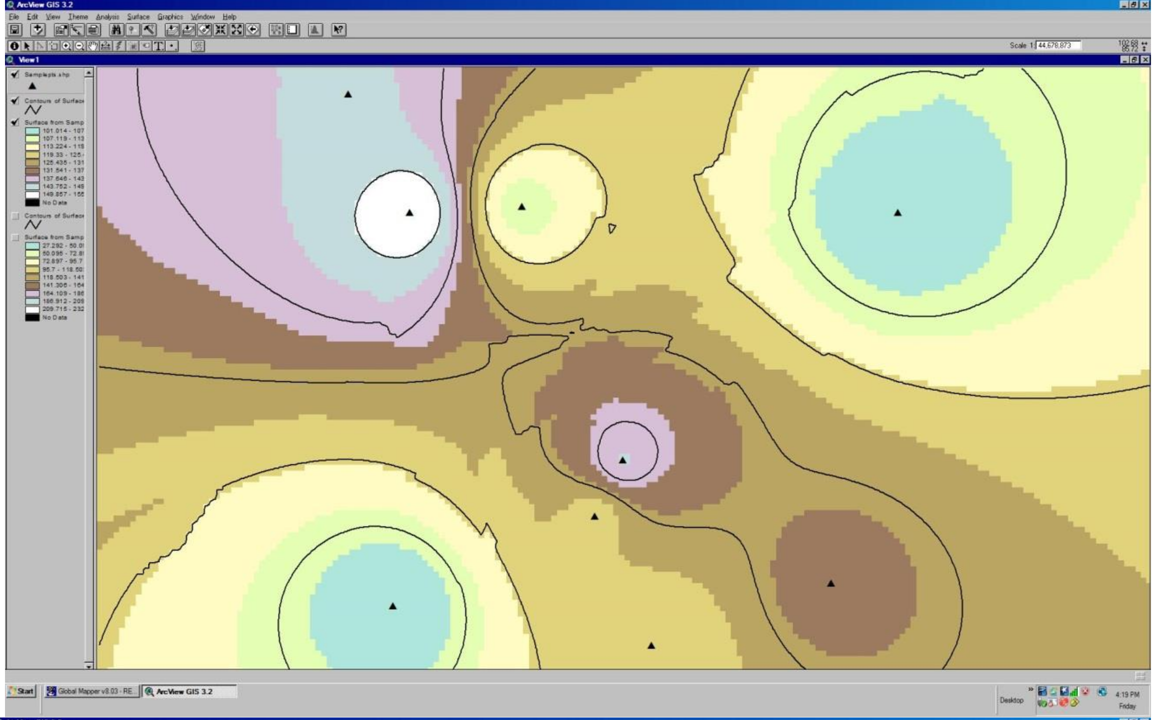
Temporal conflation

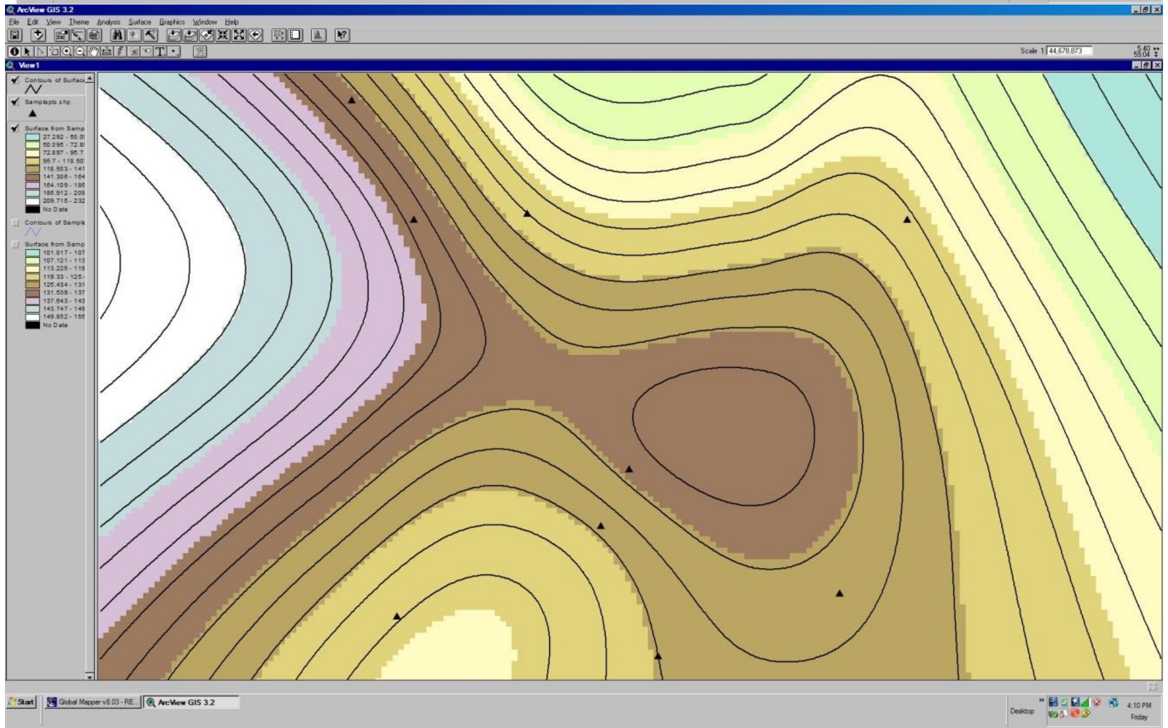




Conflation

Interpolation method uncertainty
Top: IDW
Bottom: Spline

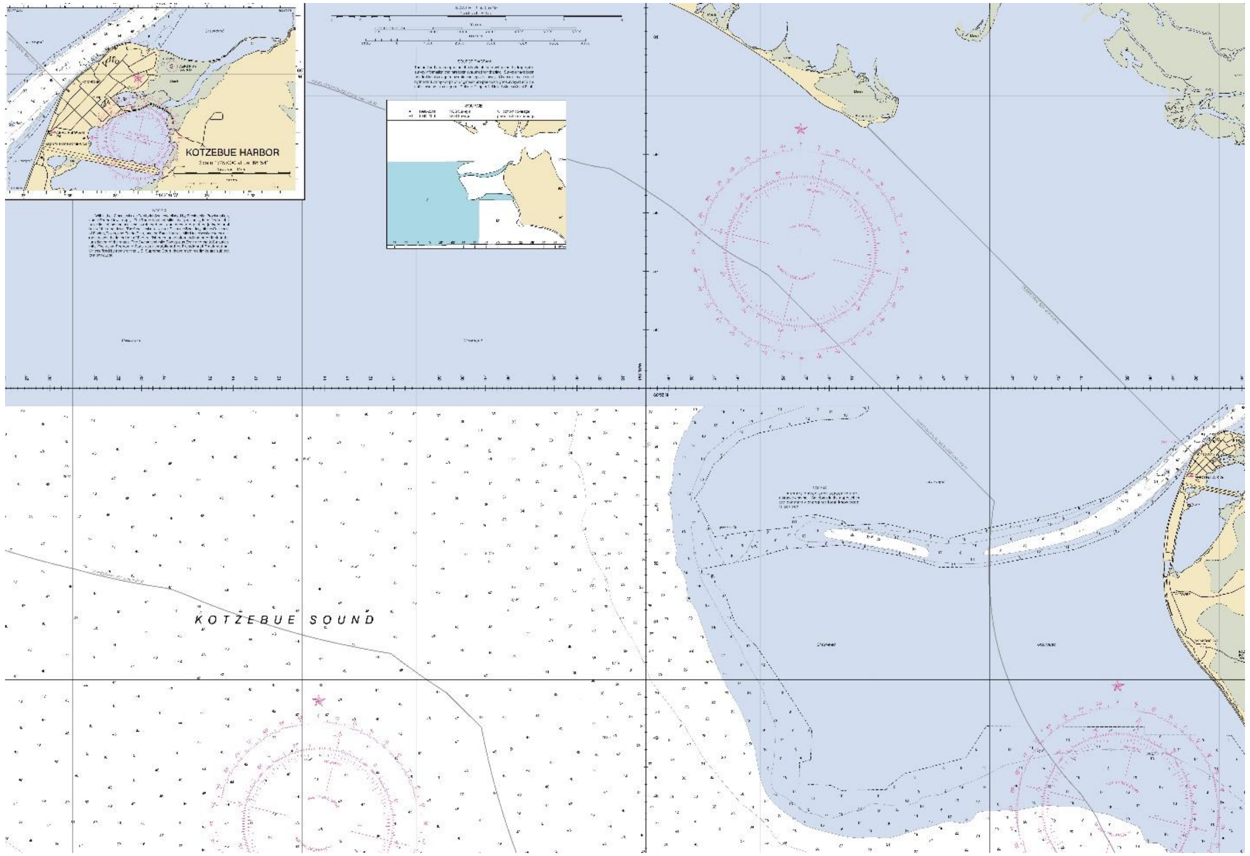


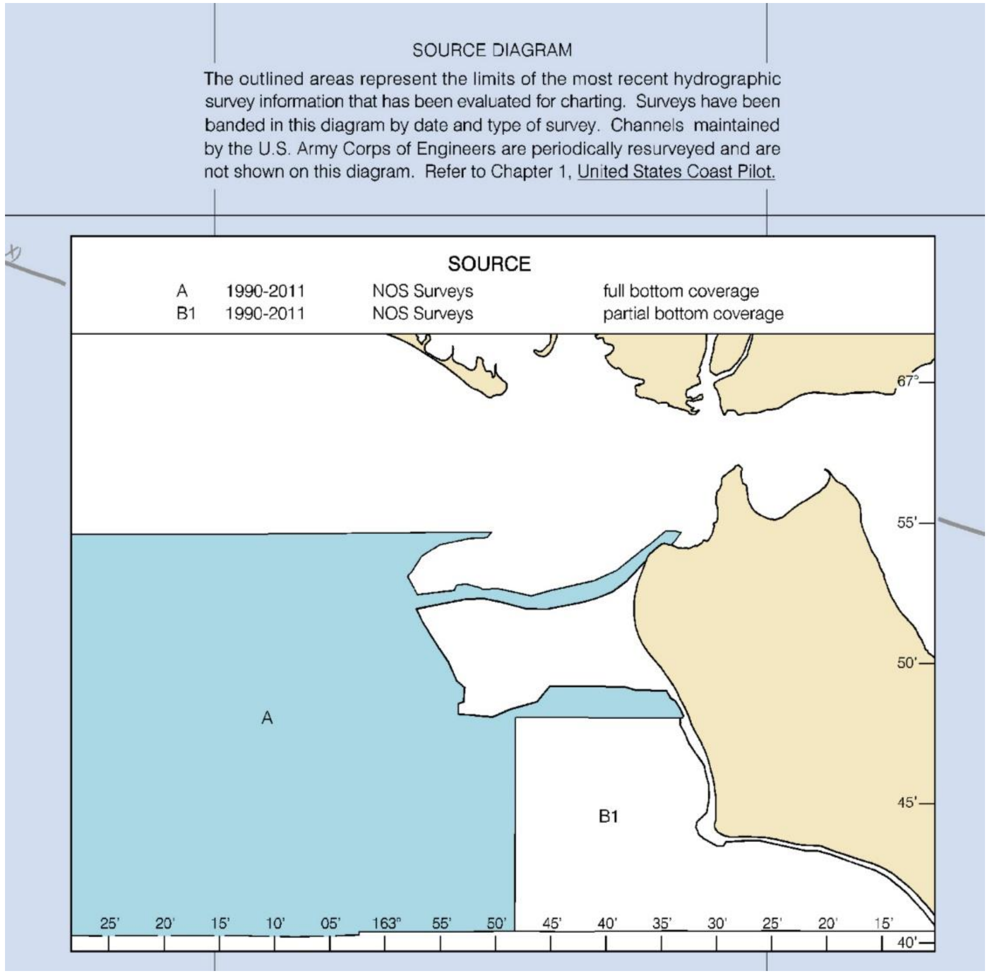


Fuzzy attributes and positions

- Positions assumed accurate
- But really, just best guess “Best Available Data”
- Differentiate best guesses from “truth”
- “Shadow map of certainty”
  - where an estimate is likely to be the most accurate
- Tracking error propagation

Source diagram: NOAA Chart (Kotzebue, AK)





Fuzzy overlay

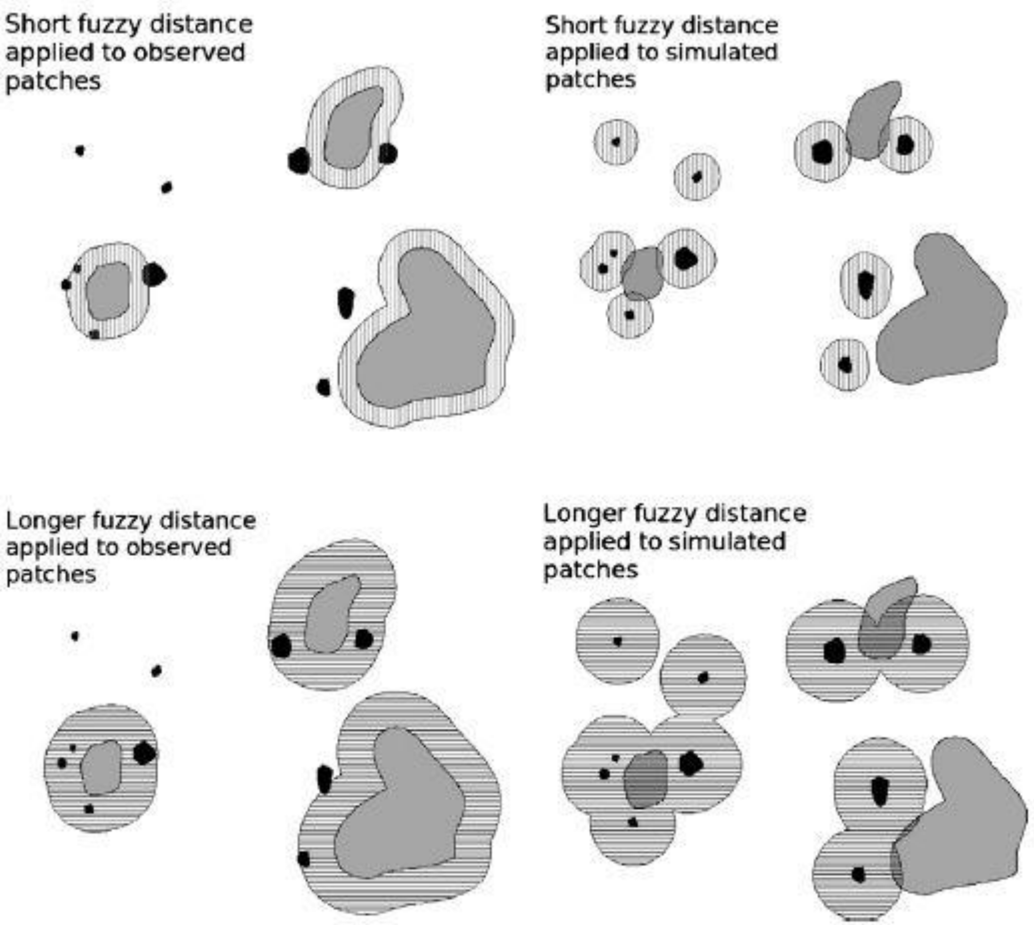


Fig. 2. Two-way fuzzy comparison between simulated and observed changes. Based upon a "hard" per pixel comparison, there is no coincidence between the observed and the simulated maps. Using increasing fuzziness (longer tolerance distance), coincidence is higher. Note that coincidence is different depending if fuzziness is applied to the observed or the simulated map.

Ecological Complexity 11 (2012) 38–45

Contents lists available at SciVerse ScienceDirect

Ecological Complexity

journal homepage: www.elsevier.com/locate/ecocom

Original Research Article

Assessing simulated land use/cover maps using similarity and fragmentation indices

Jean-François Mas [a,*], Azucena Pérez-Vega [b], Keith C. Clarke [c]

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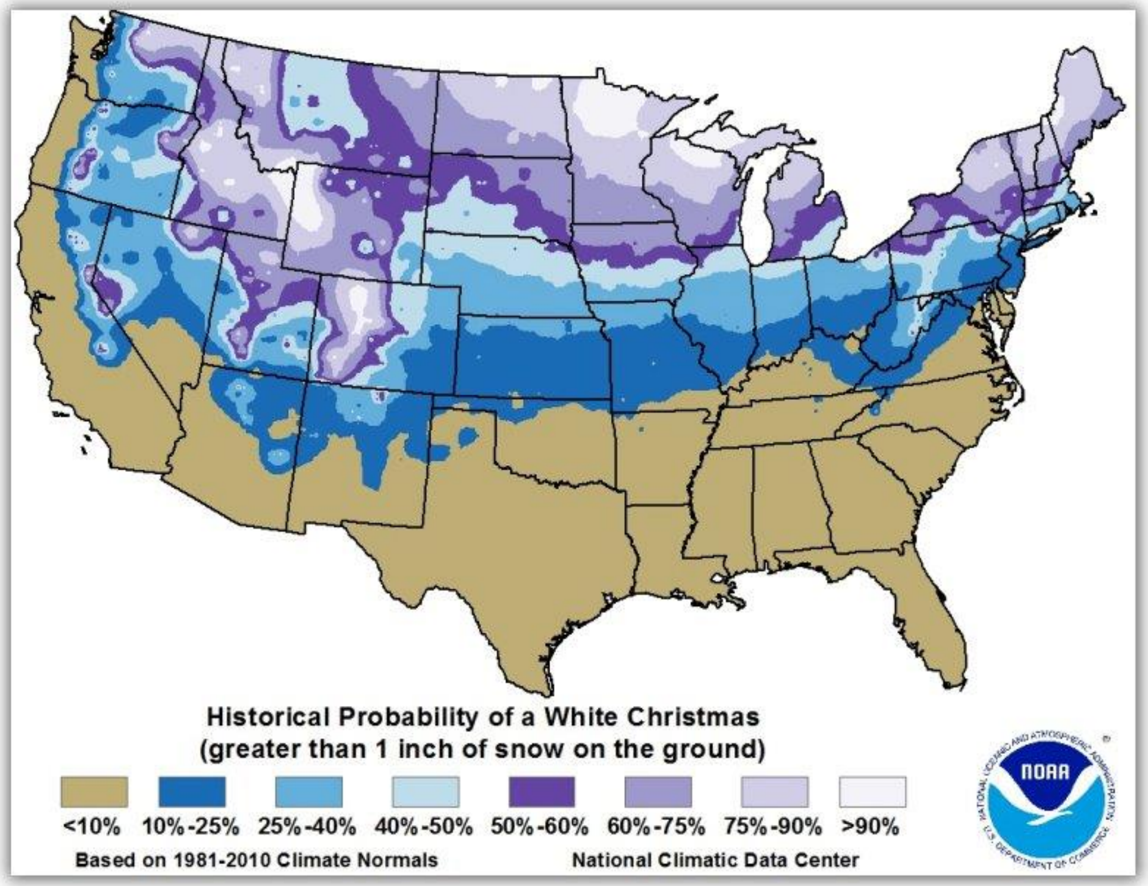
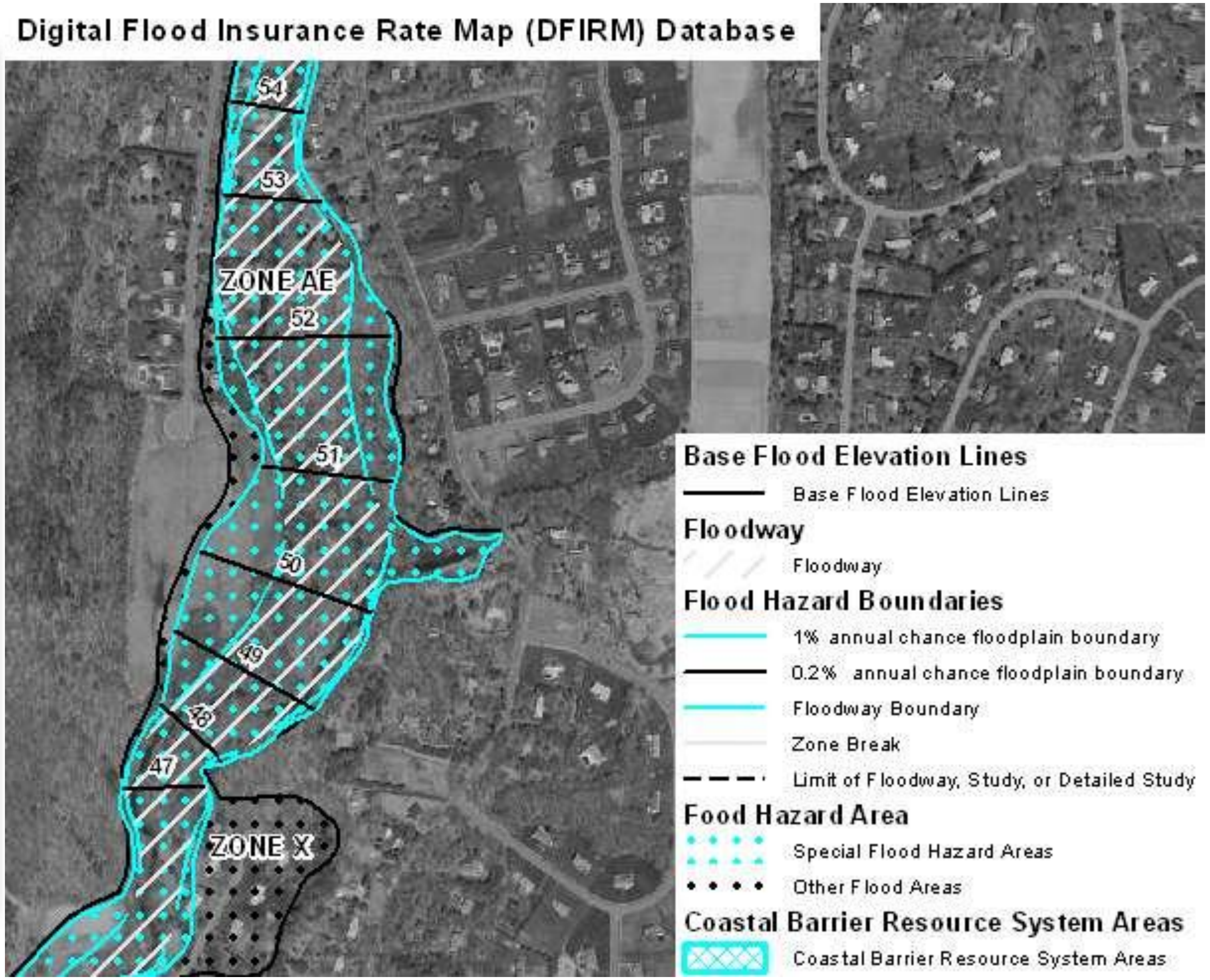
[b] Departamento de Ingeniería Civil, Universidad de Guanajuato, Av. Juárez 77, Colonia Centro, C.P. 3600 Guanajuato Gto, Mexico
[c] Department of Geography, U.C. Santa Barbara, Santa Barbara, CA 93106-4060, USA

More Strategies

- Simulation
  - Complex models
  - Describing uncertainty as “a spatially autoregressive model with parameter rho” not helpful
  - How to get message across
- Many models out there
  - Research on modeling uncertainty (NCGIA Initiative 1)
  - Users can’t understand them all
  - Given choice, most users do not want uncertainty information

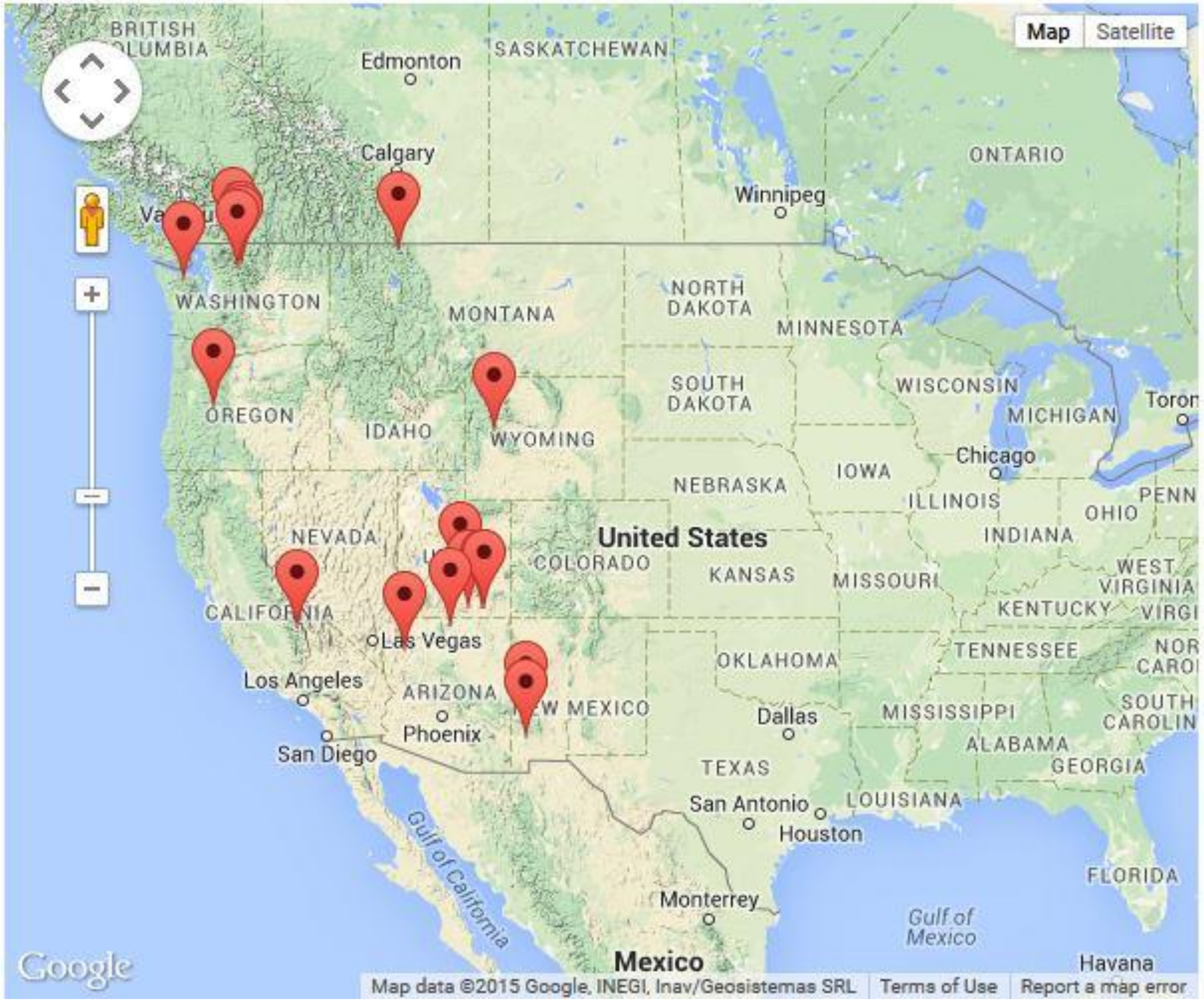
Probabilities

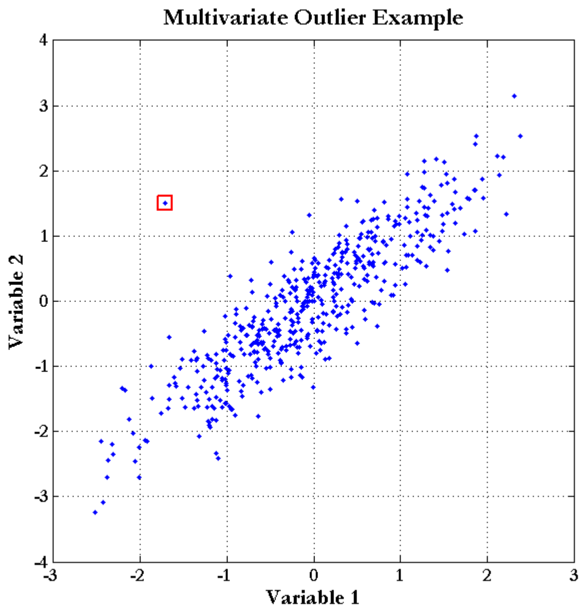




Outliers

SRTM elevation errors of over 100m vertical

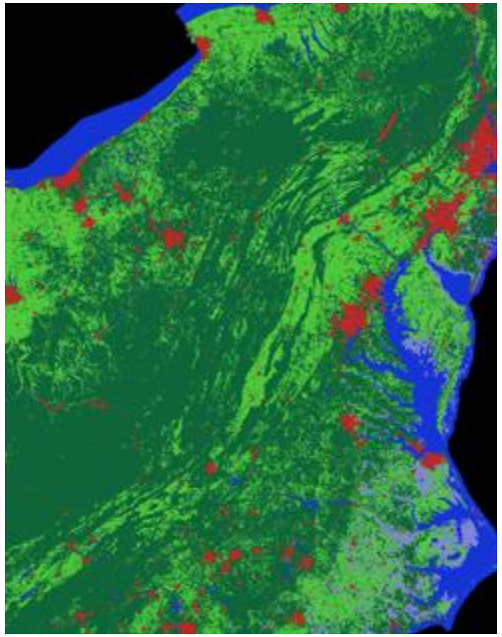




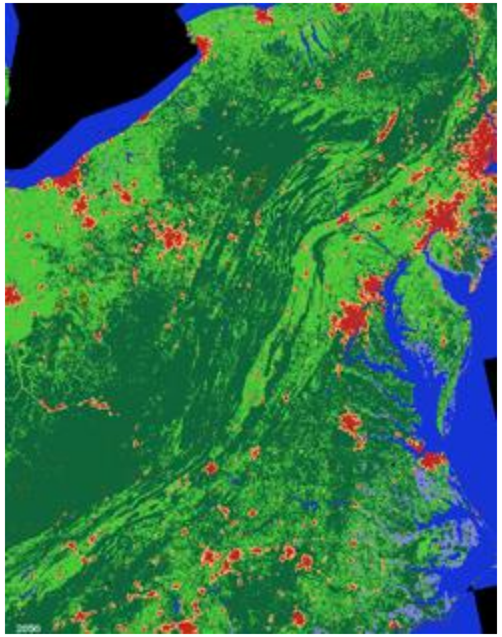
Options for dealing with map uncertainty

1. Ignore the issue completely
2. Describe uncertainty with measures (shadow map or RMSE)
3. Simulate equally probable versions of data
4. Be uncertainty-aware (trust, but verify)

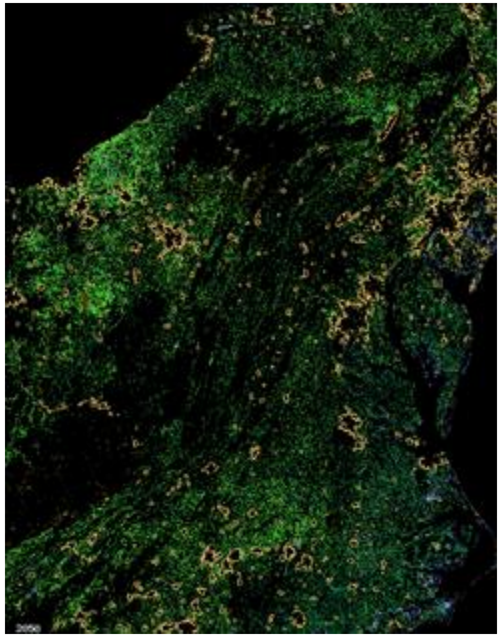
Monte Carlo Simulation



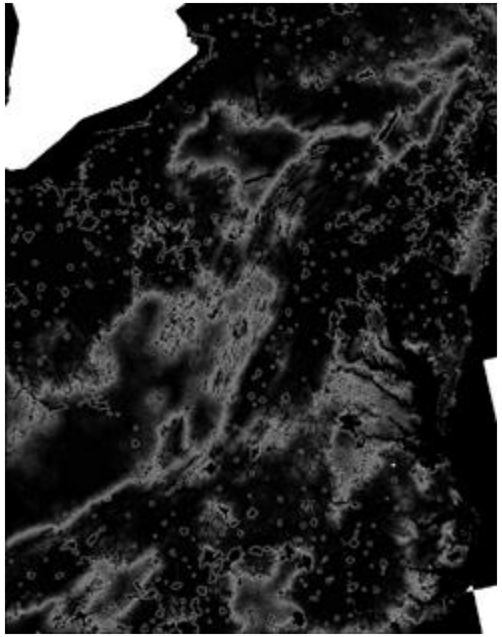
1992



2050



Change



Uncertainty (%)

http://www.geog.ucsb.edu/~kclarke/ucime/banff2000/533-jc-paper.htm

A Review of Uncertainty in Data Visualization
Ken Brodlie, Rodolfo Allendes Osorio and Adriano Lopes
http://www.comp.leeds.ac.uk/kwb/publication_repository/2012/uncert.pdf

Fig. 5 Contour band: This shows the extent of the 95% confidence interval for the zero contour, with the zero contour for the average data at each point shown for comparison.

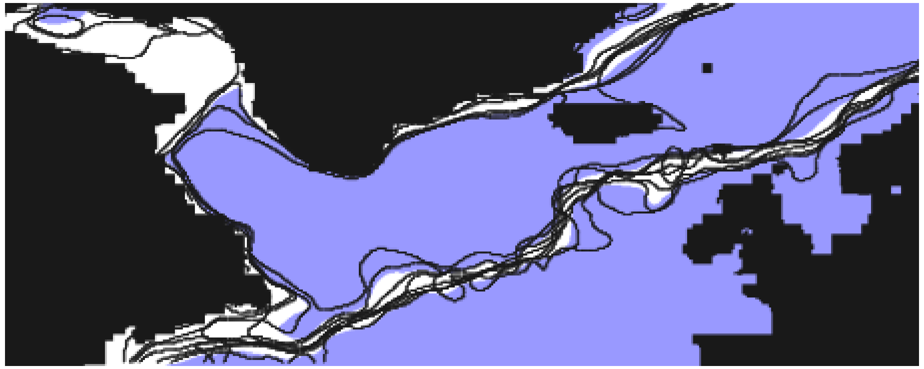


Fig. 7 Spaghetti Plot: zero contours from each of the eight individual models, superimposed on 95% confidence band

Fig. 6 Fuzzy contour: This shows the value of the t-statistic from the hypothesis test with a colour mapping from sea-blue to black based on the size of the t-statistic.

Kriging uncertainty in R

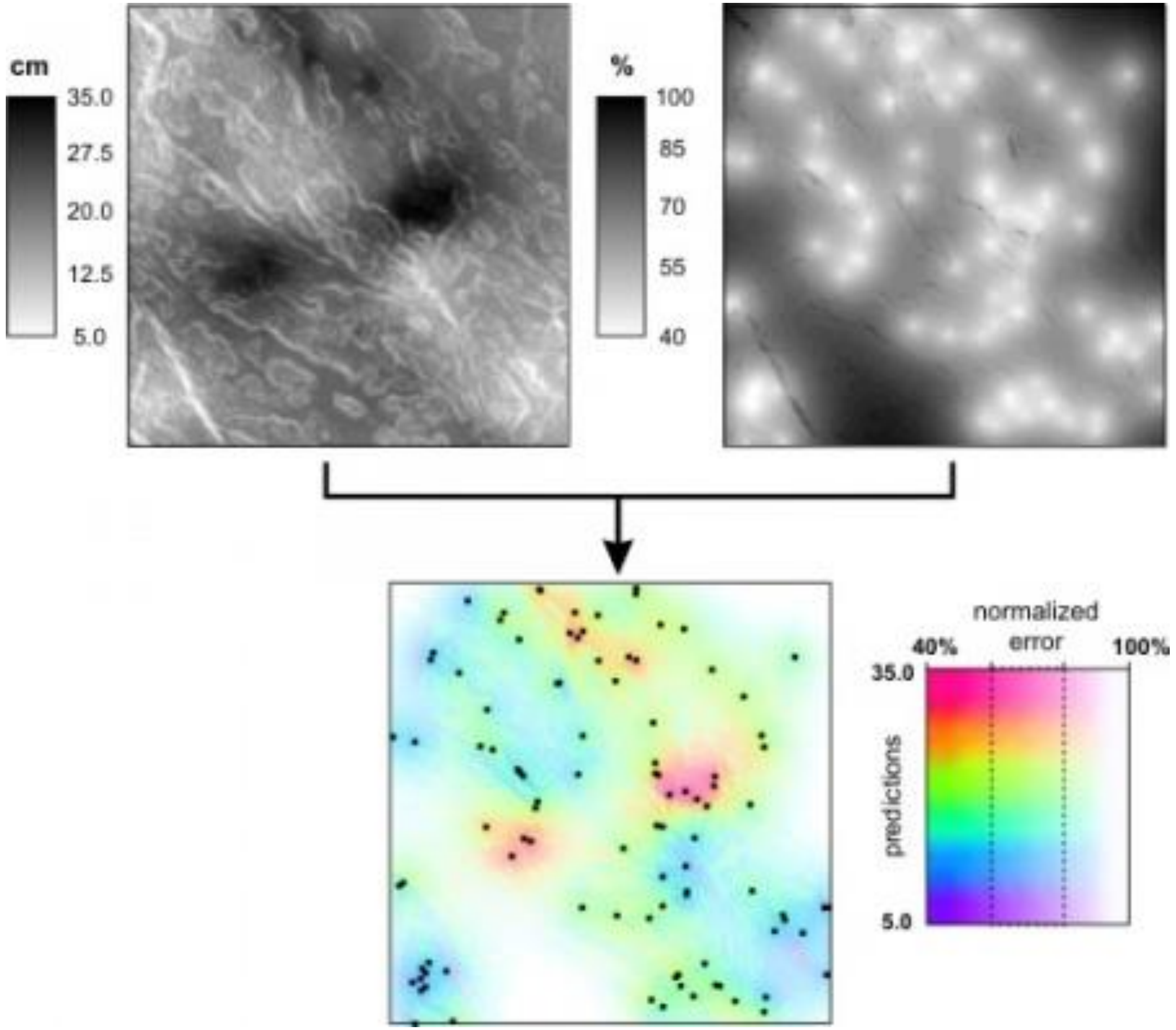
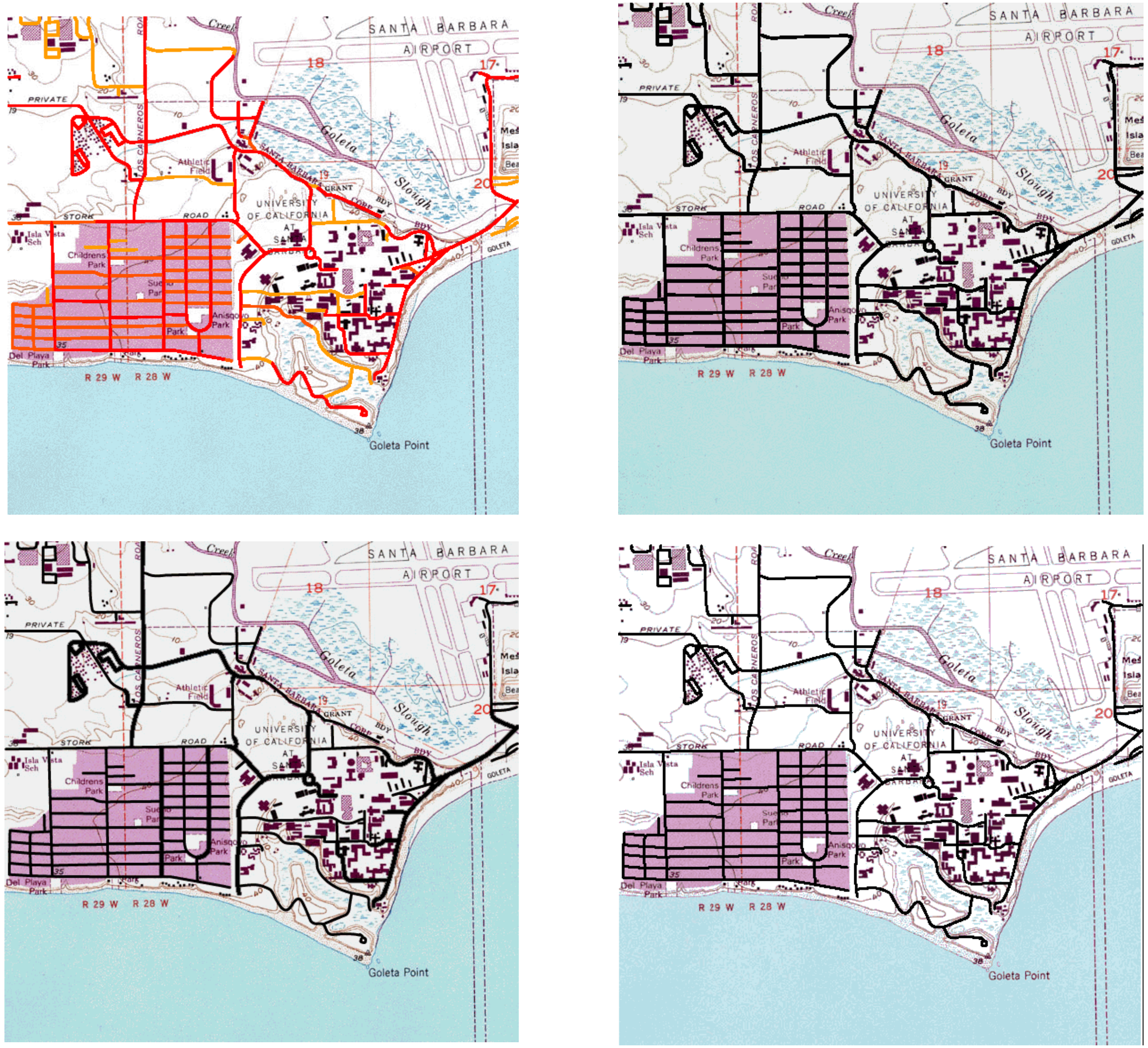


Figure: Visualisation of uncertainty for a quantitative variable (topsoil thickness in cm) interpolated using regression kriging: uncertainty included with whiteness and the accompanying two-dimensional legend.

Visualizing Uncertainty



Summary

- All data are uncertain
- Uncertainty types include lineage, positional accuracy, attribute accuracy, completeness and logical consistency
- Error due to scale, method, interpretation, source, bias
- Methods for dealing with error include ignoring it, quantification, simulation
- Few methods explore integrating error and uncertainty directly
- People have a hard time dealing with probabilities, let alone expected error information