

# Visualizing Uncertainty

GEOG 5201 – Spring 2022

# Outline

- General methods for depicting uncertainty
  - Maps compared
  - Maps combined
  - Interactive data exploration tools
- Visual variables for depicting uncertainty
  - Intrinsic/extrinsic (for maps combined)
  - Basic/additional

# Recall Uncertainty

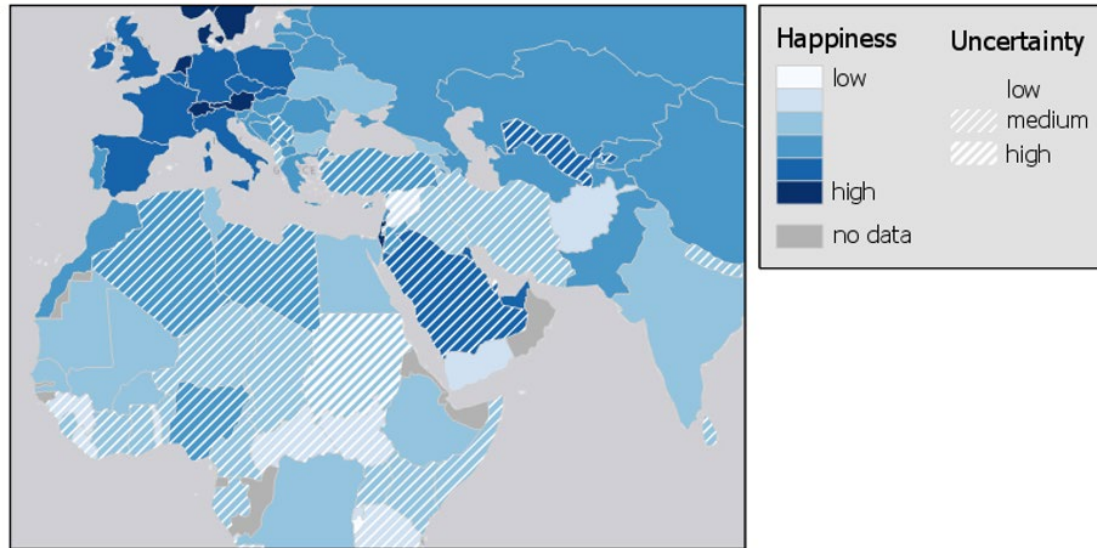
- Uncertainty is **the potential variation in values of an attribute** at a spatial location
- Uncertainty emerges during multiple stages of map-making
  - Uncertainty in the raw data
  - Uncertainty in processing data
  - Uncertainty in the visualization

# General Methods for Depicting Uncertainty

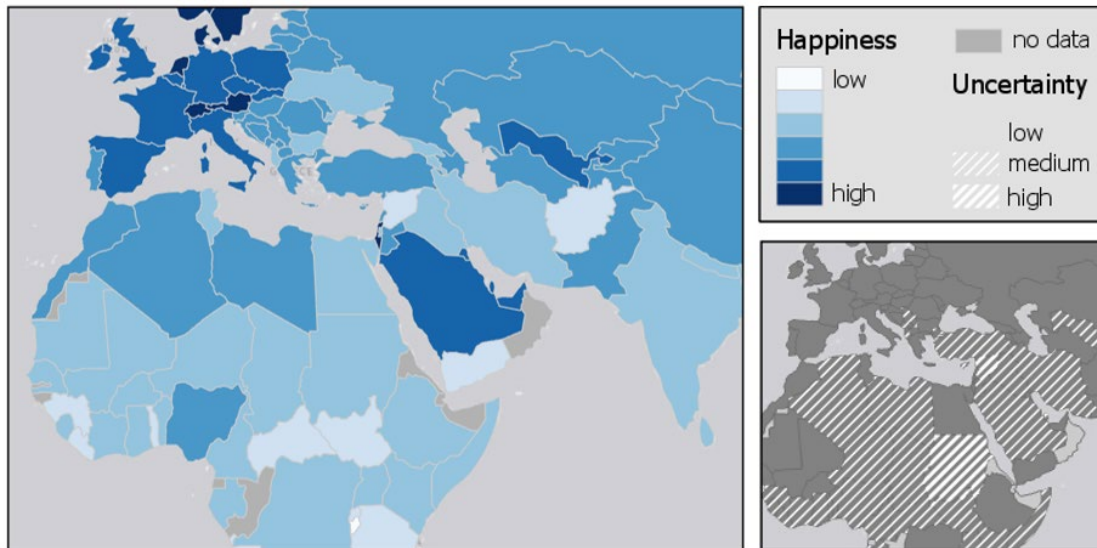
- **Maps Compared** – 2 maps
  - Individual maps can be shown for both an attribute and its associated uncertainty
- **Maps Combined** – 1 map
  - The attribute and its uncertainty can be displayed on the same map – given the appropriate visual variables

In general, the combining method is a more popular technique, though a compare technique might be useful if the primary map is sufficiently complex, and thus adding overlay would make the map difficult to comprehend

Maps combined



Maps compared

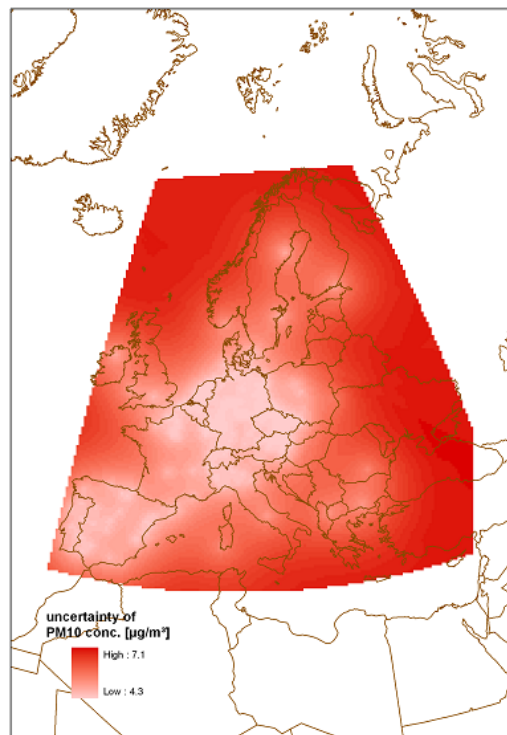
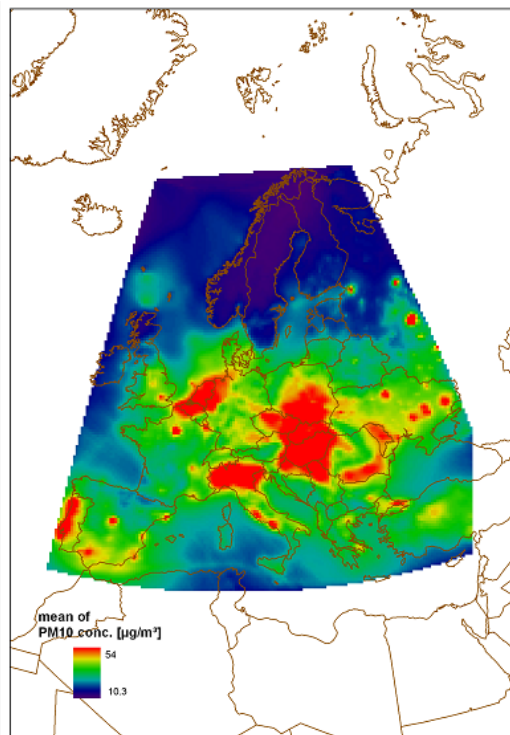


Combining (top) vs. comparing (bottom) uncertainty visualization techniques

# Question 3-2-1

Which method do you think is used to create the map below?

- i. Maps compared
- ii. Maps combined



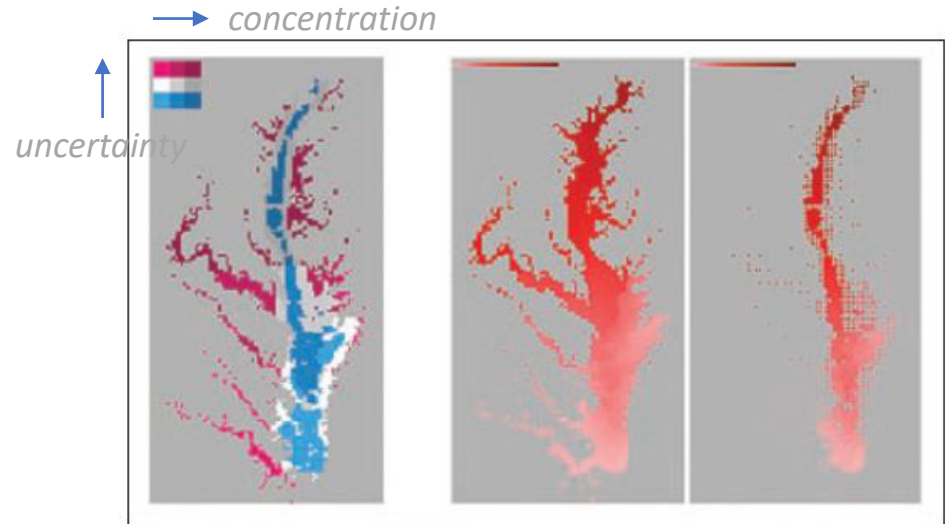
# General Methods for Depicting Uncertainty

- **Interactive data exploration tools**

- Allow easy manipulation of the display, both the attribute and its uncertainty
- Users need control over depictions of uncertainty
- Strategies
  - Bivariate representations that depict data and uncertainty together. Users control which component is visually dominant
  - Depict only data but allow users to control an uncertainty threshold above which the data are not represented or are represented less clearly
  - Others: animation

# General Methods for Depicting Uncertainty: Interactive Data Exploration Tools

- Left: Bivariate representation that depicts data and uncertainty together
- Right: Depicts only data and utilizes an uncertainty threshold above which the data are not represented

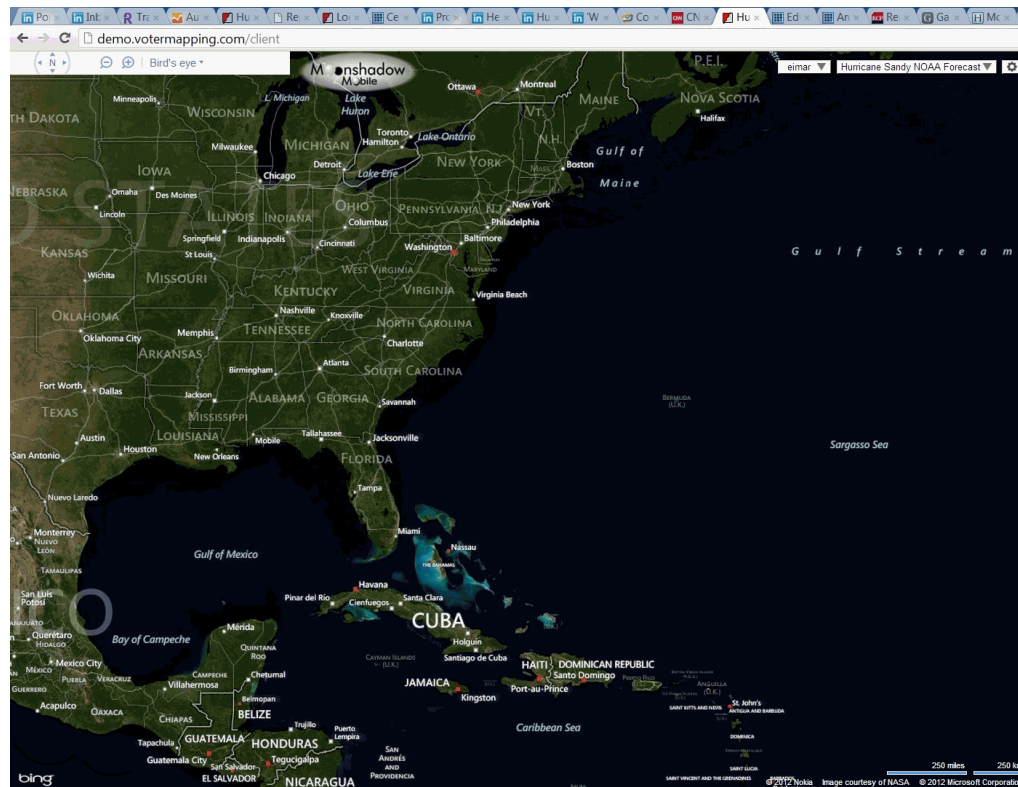


**Figure 6.** Alternative depictions of data (inorganic nitrogen in Chesapeake Bay) and uncertainty of data interpolated from sparse point samples. Left view shows bivariate depiction in which dark = more nitrogen and certainty is depicted with a diverging color scheme (blue = most certain and red = most uncertain). The right view depicts data in both panels (dark = more nitrogen), with the right side of this view showing the results of interactive focusing on the most certain data.



# General Methods for Depicting Uncertainty: Interactive Data Exploration Tools

- Animation has been employed as a method for understanding uncertainty in space-time process

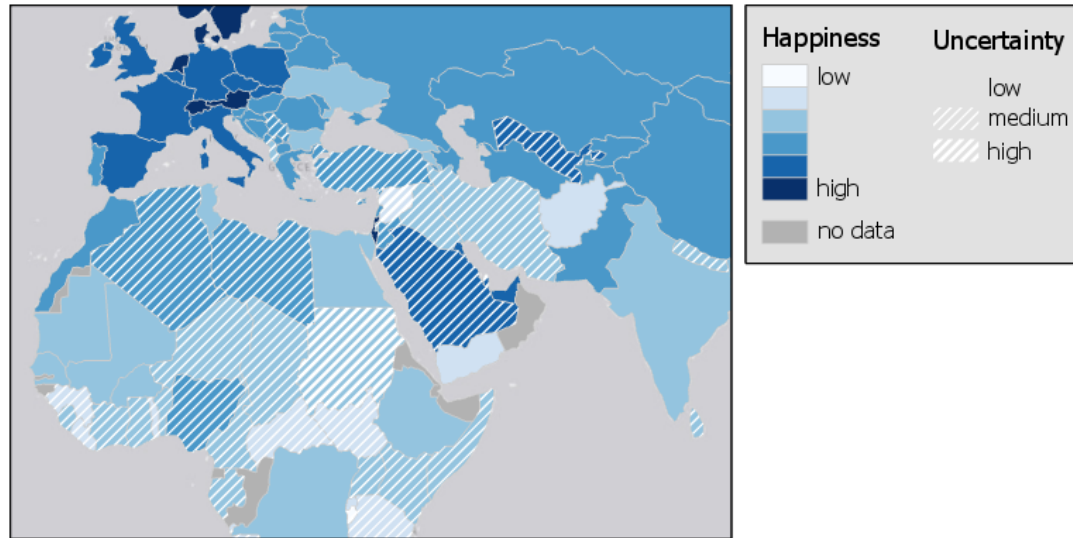


# Visual Variables for Depicting Uncertainty

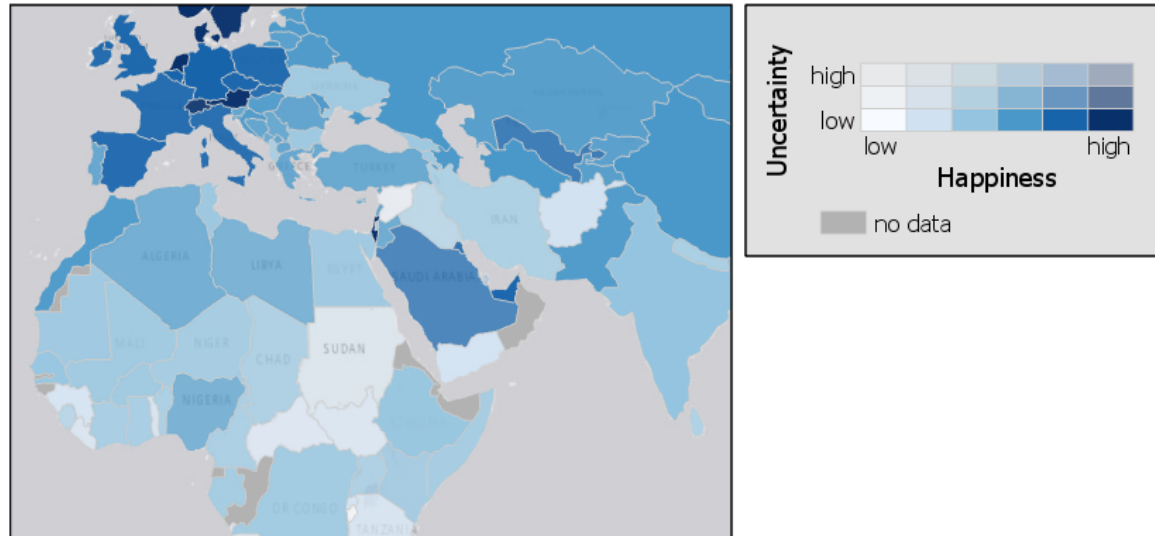
Assume the “*maps combined*” approach

- Intrinsic visual variables
  - Vary the existing object’s appearance to show associated uncertainty
  - Cannot be visually separated from the visualization of one or more other variables
  - Example: vary the saturation of colored tones on a choropleth map
- Extrinsic visual variables
  - Addition of geometric objects to highlight certain information
  - Easier to interpret separately
  - Example: add glyphs/dials/arrows/bars to display uncertainty (solely or in addition to other attributes)

Extrinsic visual variables  
hatched fill overlay

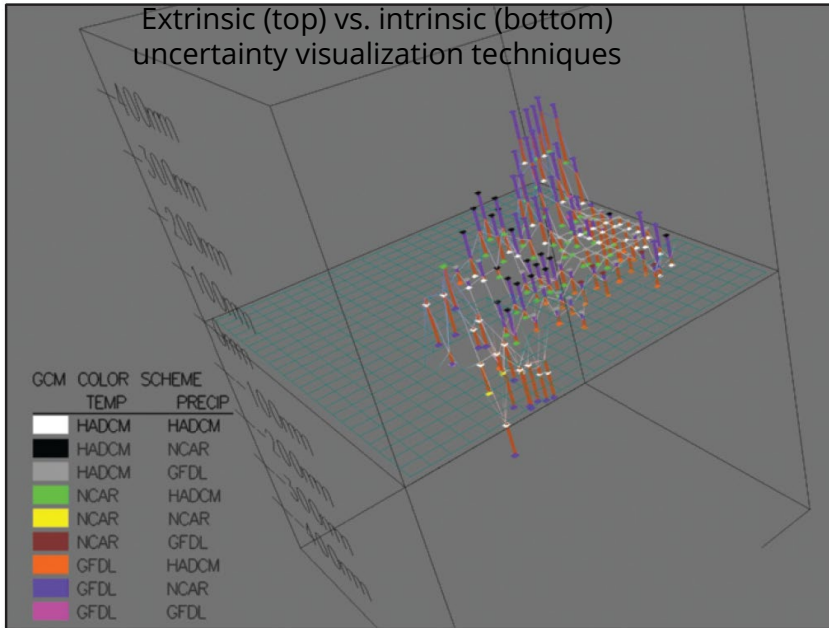


Intrinsic visual variables  
transparency

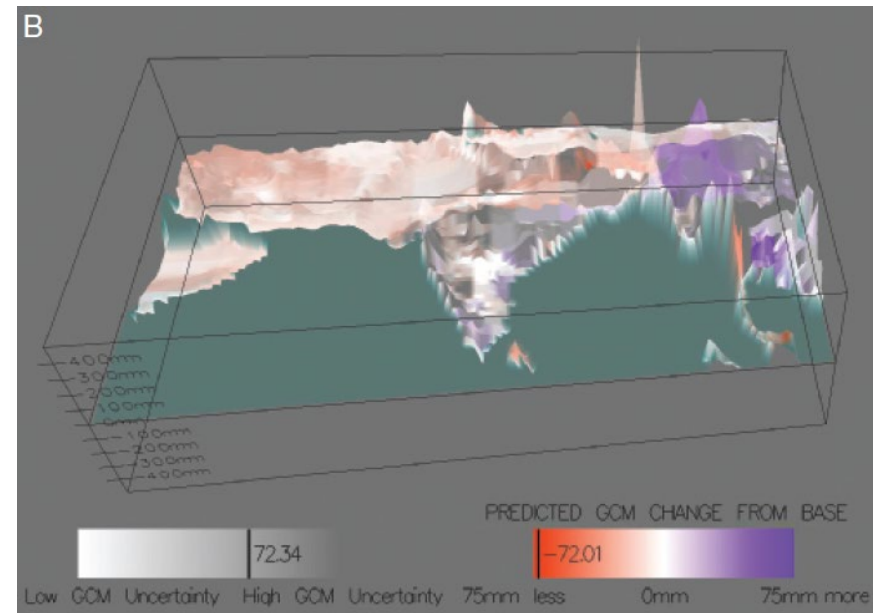


Extrinsic (top) vs. intrinsic (bottom) uncertainty visualization techniques

### Error bar overlay

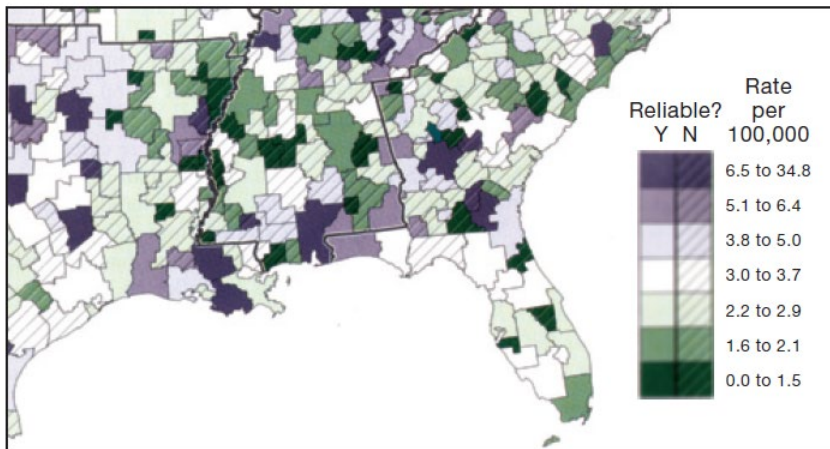


### Transparency



### Intrinsic visual variables

### Hatched fill overlay

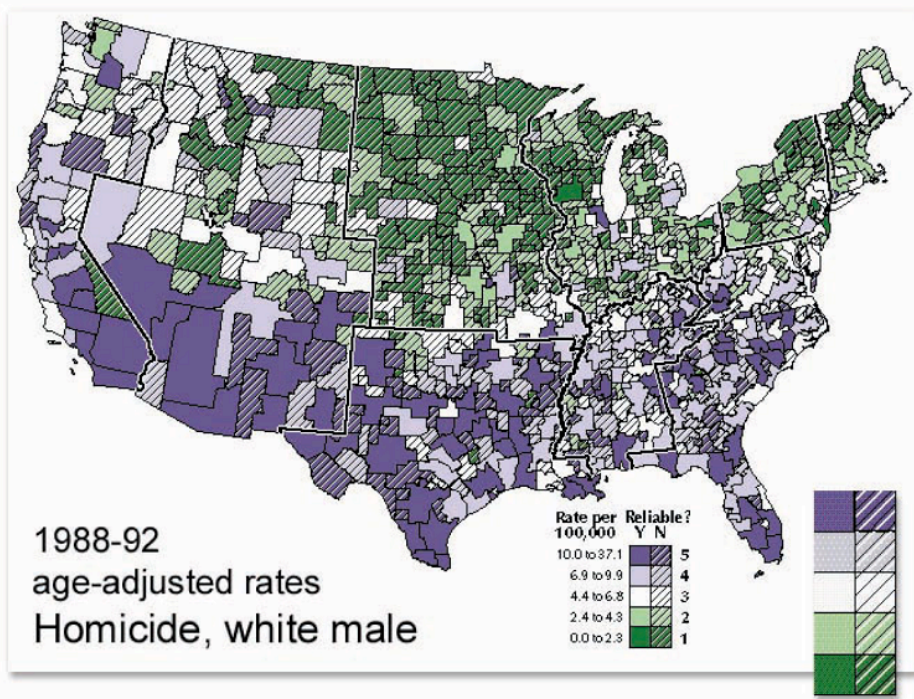


### Extrinsic visual variables

# Question 3-2-2

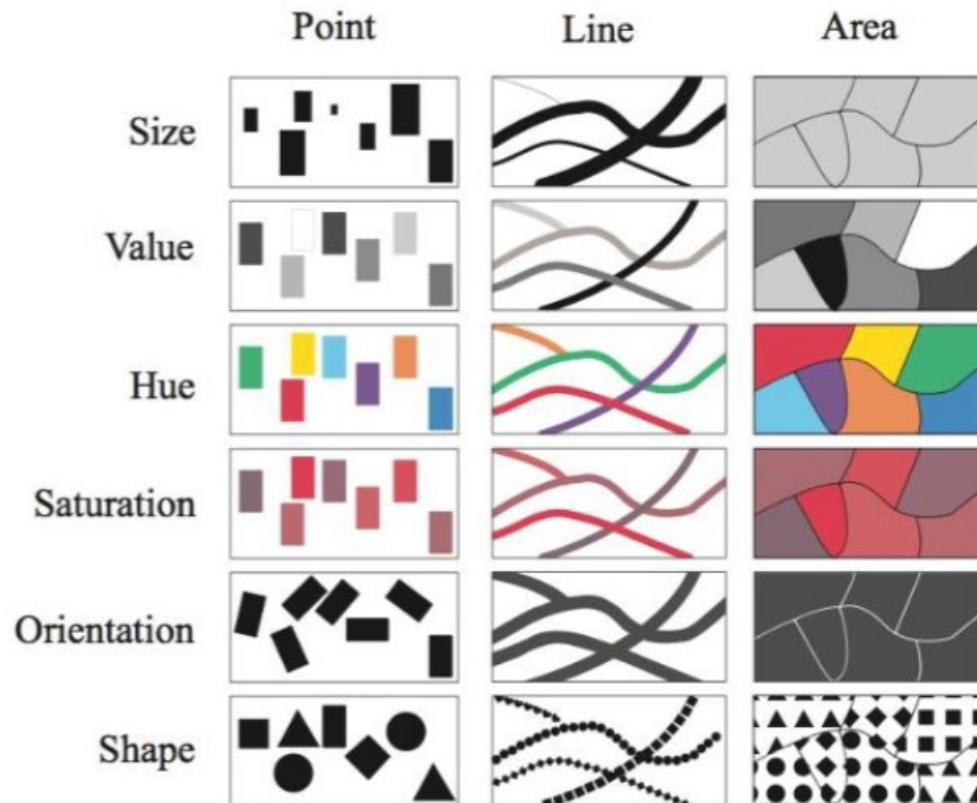
Which type of visual variables do you think is used to create the map below?

- i. Intrinsic visual variable
- ii. Extrinsic visual variable



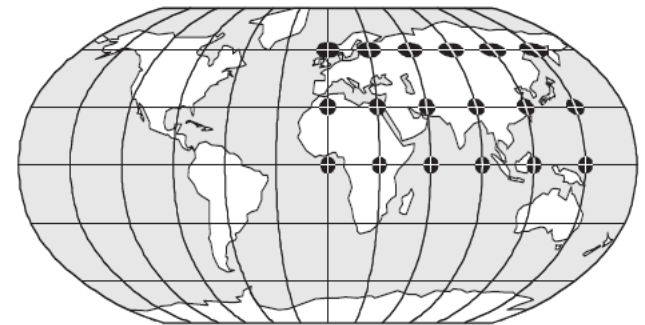
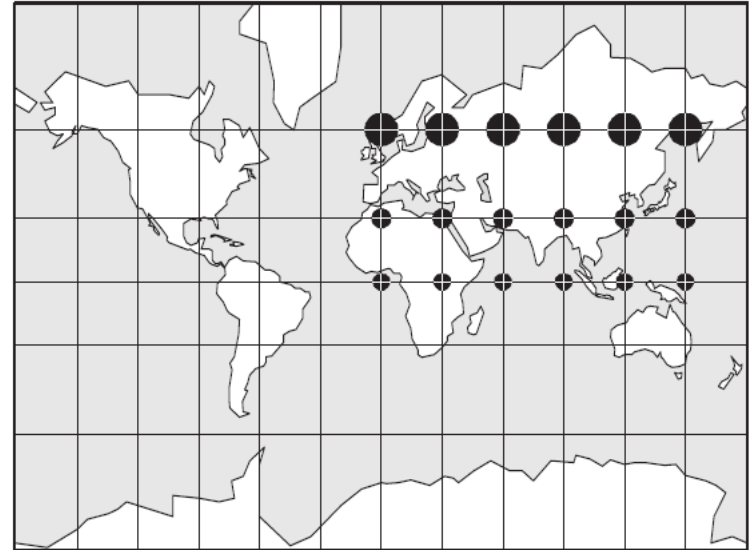
# Basic Visual Variables

- Any **basic visual variable** can be adapted to demonstrate uncertainty



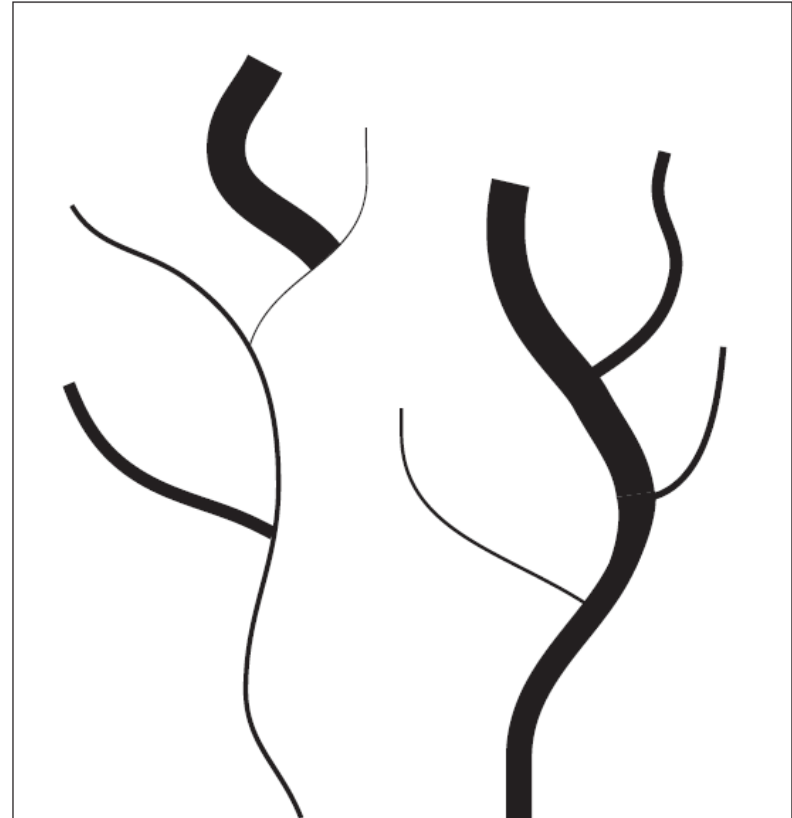
# Basic Visual Variables

- Example (extrinsic): Tissot's indicatrix
  - Visual variables of **size** and **shape** represent the ability of various map projections to maintain correct **size** and **angular** relationships



# Basic Visual Variables: Confusing Applications

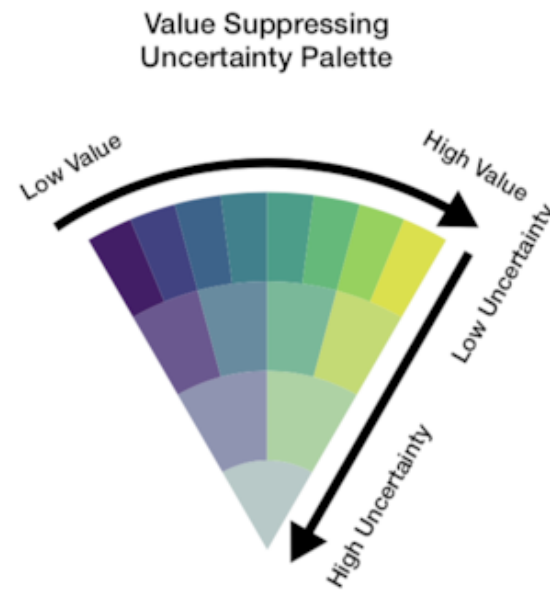
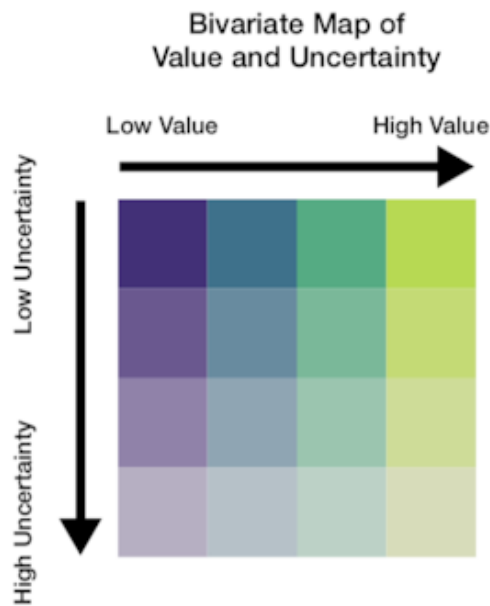
- Basic visual variables can be confusing sometimes
- Example (intrinsic): use **size** to represent uncertainty in stream **position**
  - A wide line normally would be associated with greater discharge

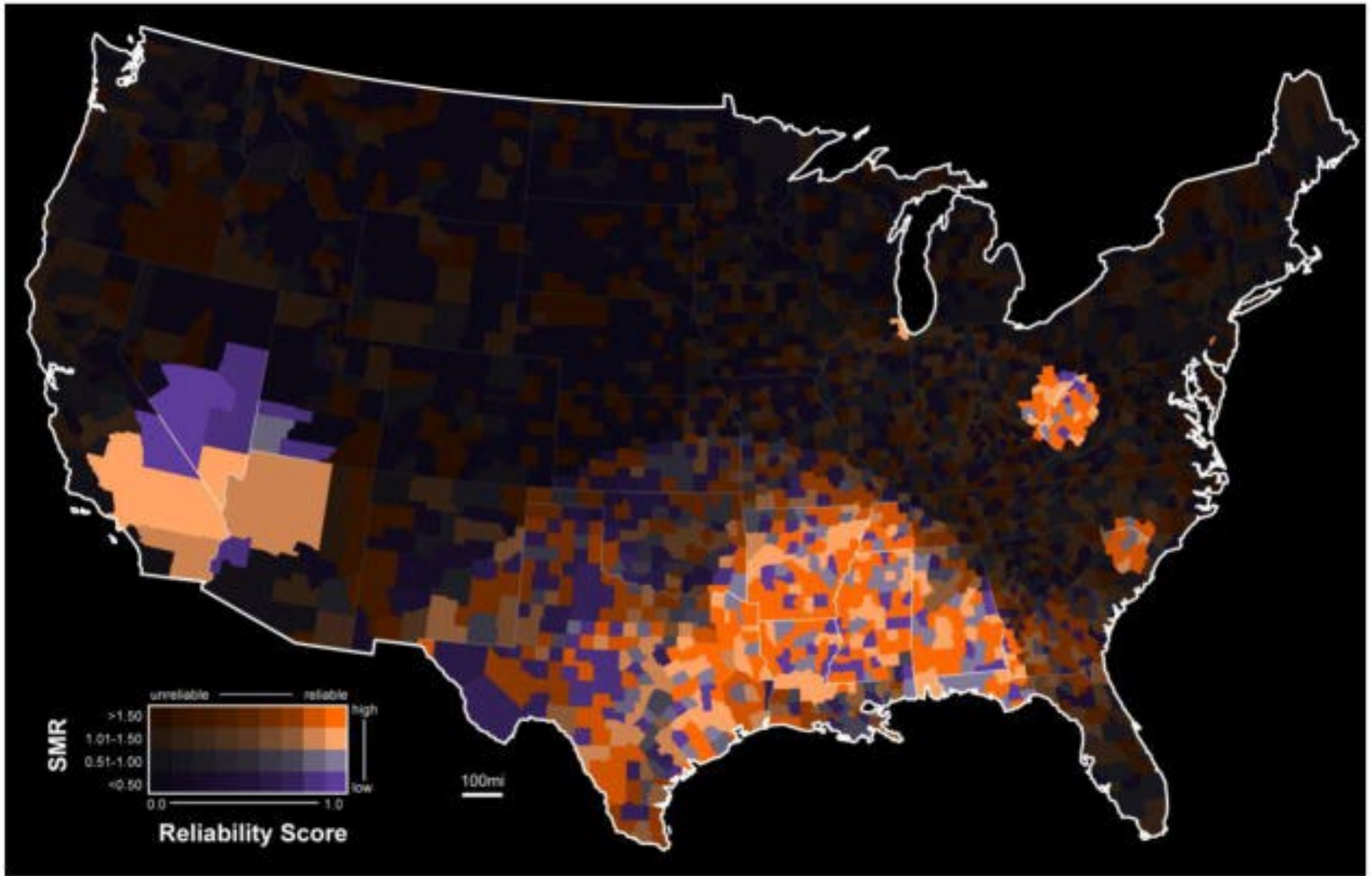




# Basic Visual Variables: Saturation

- **Saturation** is particularly logical for depicting uncertainty
  - Pure/saturated/vibrant hues: certain
  - Unsaturated hues (gray): uncertain

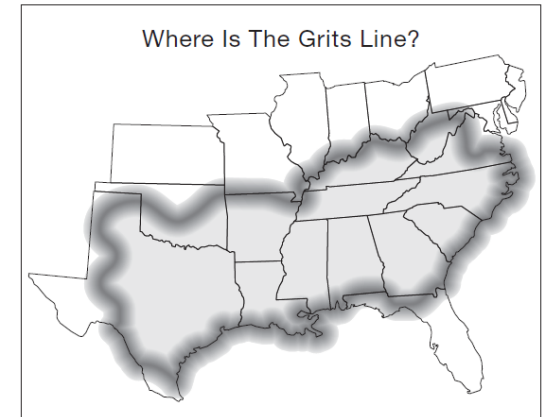




A value-by-alpha map of 2000-2004 US cervical cancer mortality aggregated to the county level

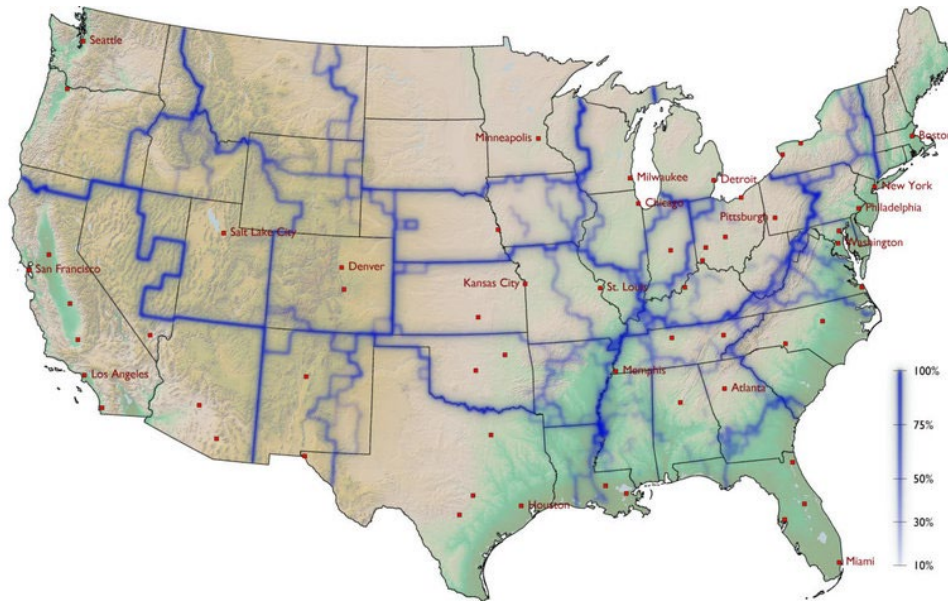
# Additional Visual Variable -- Clarity: Crispness

- Crispness: sharpness of boundaries
  - Crisp – reliable data
  - Fuzzy – uncertain data



# Additional Visual Variable -- Clarity: Crispness

## A 'Whom Do You Hang With?' Map Of America



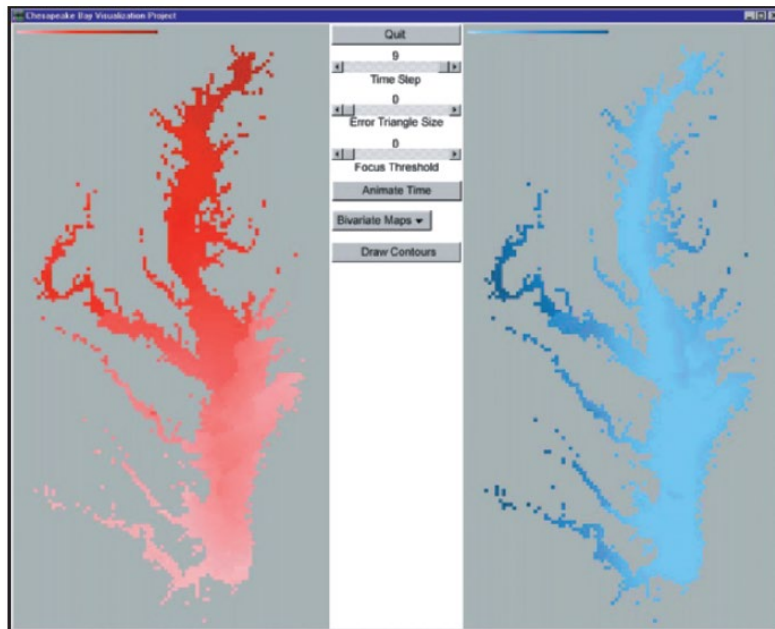
Deep blue boundaries (crisp)  
where the majority of the money is  
spent; high degree of certainty

Light blue boundaries (fuzzy)  
where limited amount of money  
goes; low certainty

“This one was built by tracking dollar bill circulation. There've been similar maps built from phone call data. The idea here is to show America not as 50 states, but as regions where people do stuff together.”

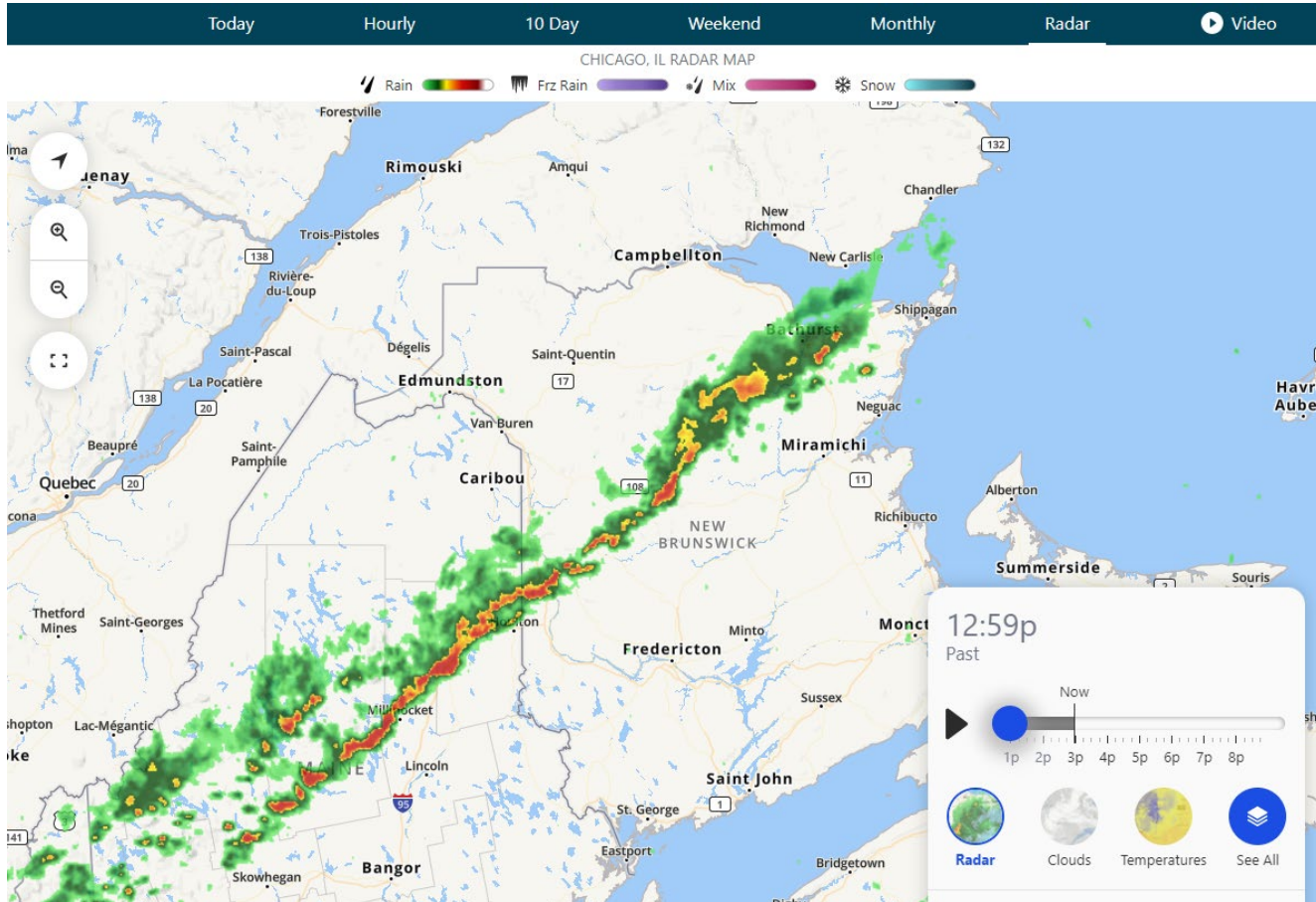
# Additional Visual Variable -- Clarity: Resolution

- Resolution: level of detail in the spatial data underlying an attribute
  - Higher (finer) – more certain
  - Lower (coarser) – less certain



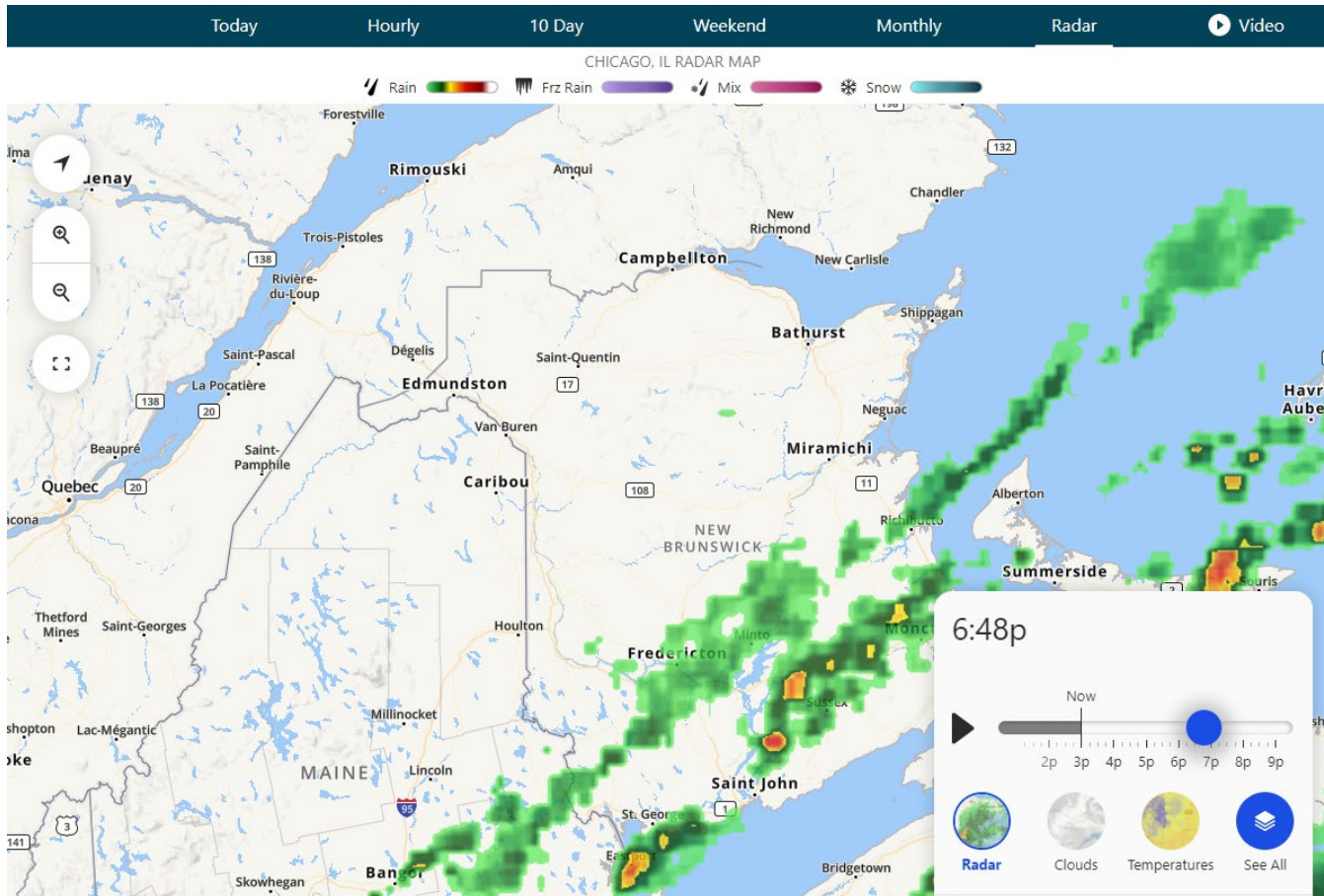
# Additional Visual Variable -- Clarity: Resolution

## Finer resolution for historical data (past)



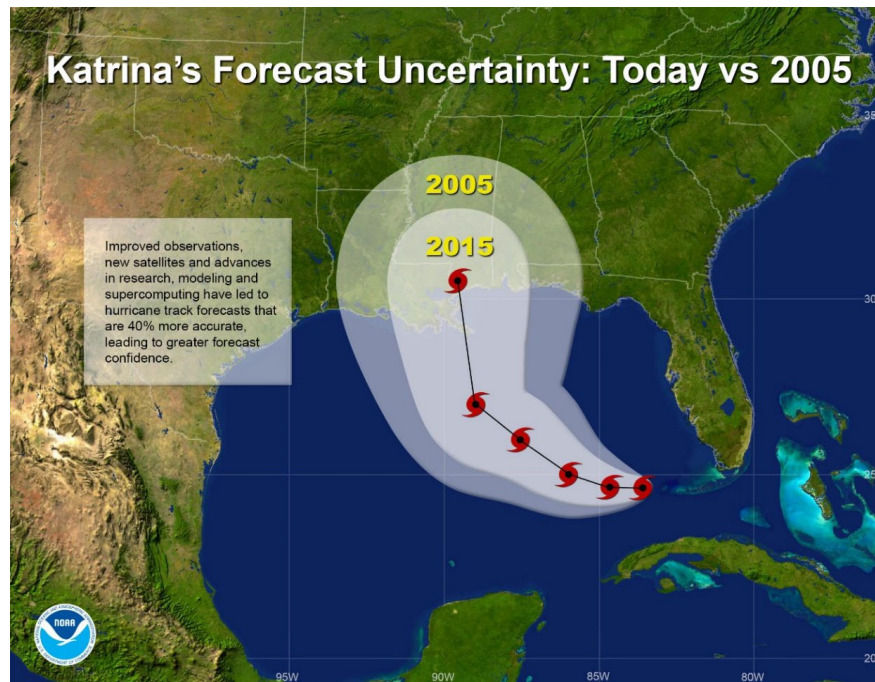
# Additional Visual Variable -- Clarity: Resolution

## Coarser resolution for estimated data (future)



# Additional Visual Variable -- Clarity: Transparency

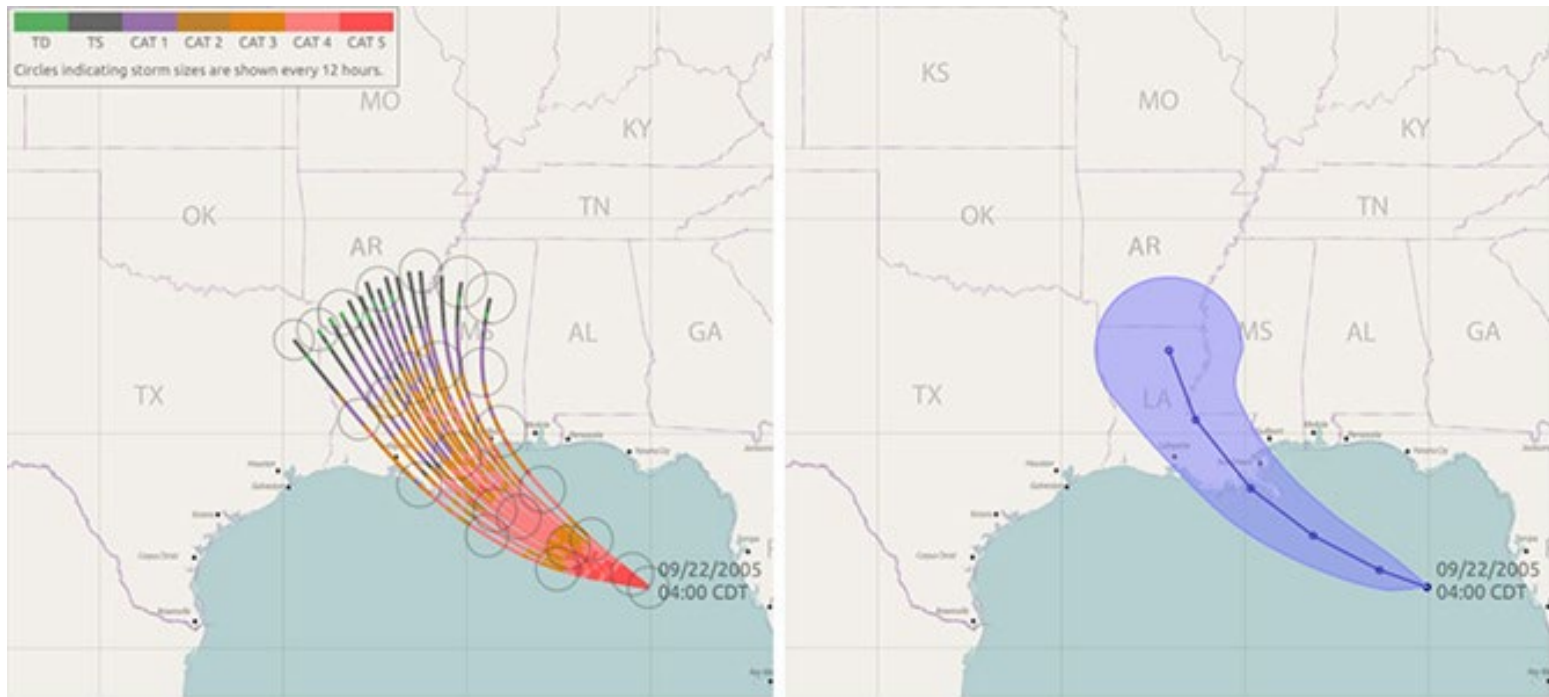
- Transparency: the ease with which a theme can be seen through a “fog” placed over that theme
  - Not easily seen through fog – reliable data
  - Easily seen through fog – uncertain data





# Additional Visual Variable -- Clarity: Transparency

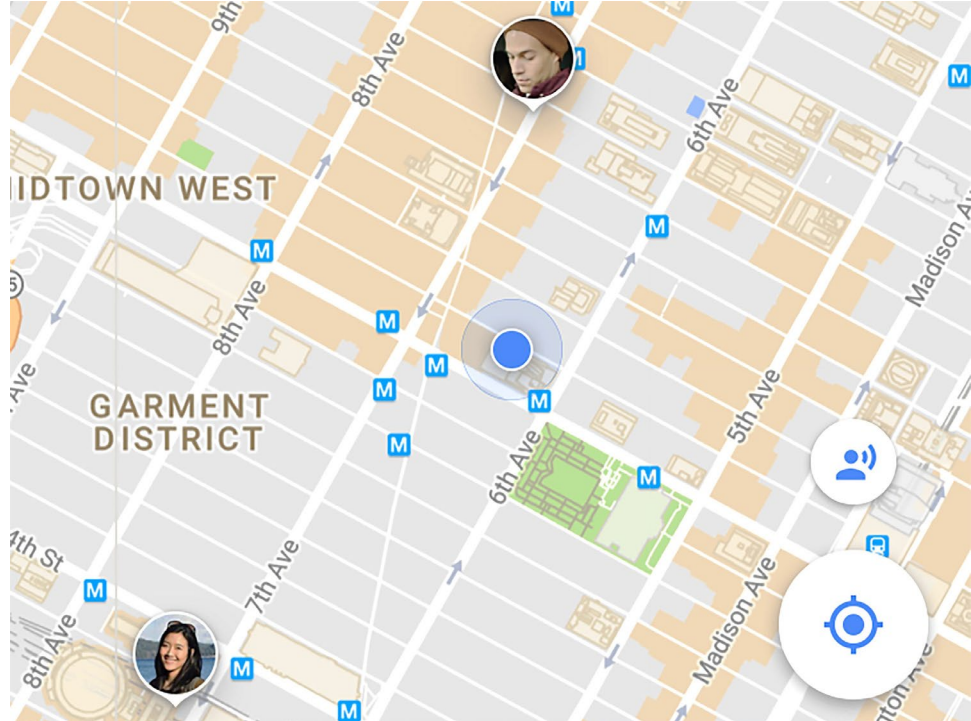
- Showing multiple possibilities vs. Using “fog”



# Question 3-2-3

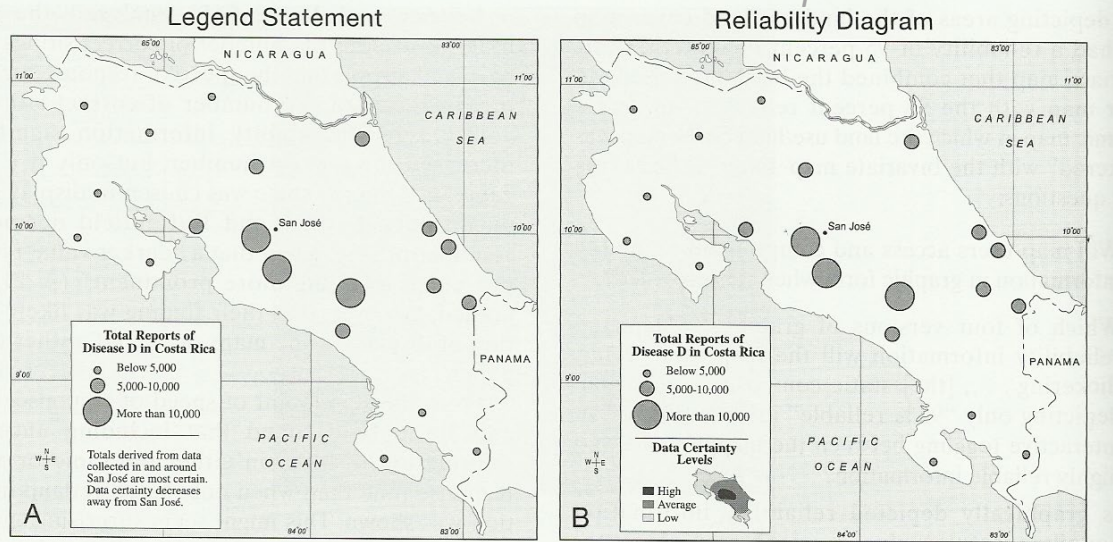
Which visual variable does Google use to depict positional uncertainty?

- i. Saturation
- ii. Resolution
- iii. Transparency



text

Indicator map



crispness

Focus

saturation Value

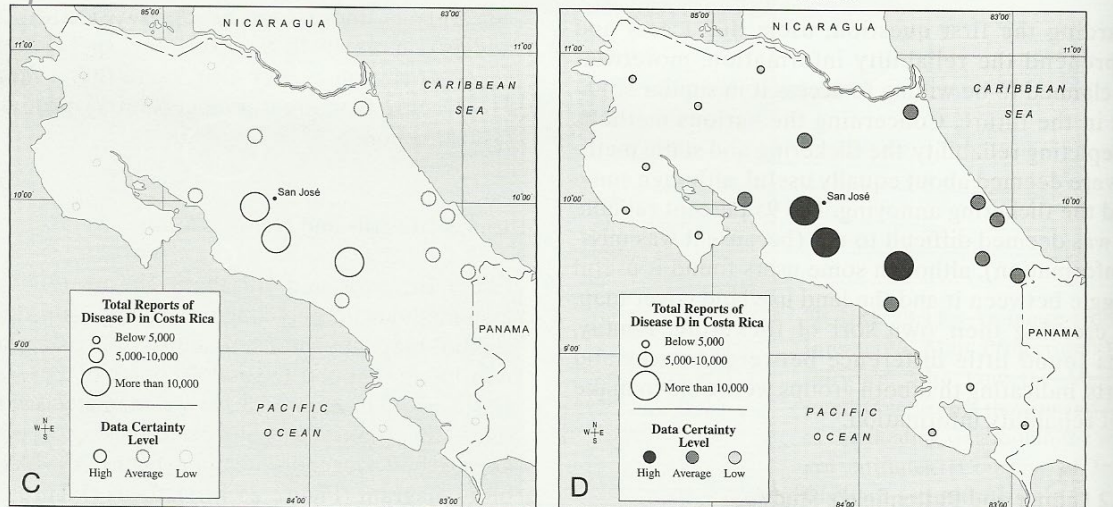


FIGURE 23.14 Approaches that Edwards and Nelson (2001) used to depict uncertainty on proportional symbol maps. (Courtesy of North American Cartographic Information Society.)

- More studies are needed to evaluate the effectiveness of uncertainty visualization tools
- This is an example of such as study
- Laura Edward and Elisabeth Nelson (2001)
- Result: Focus (bottom left) outperformed value (bottom right)