Visualizing Uncertainty

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PSYC 6135: Psychology of Data Visualization
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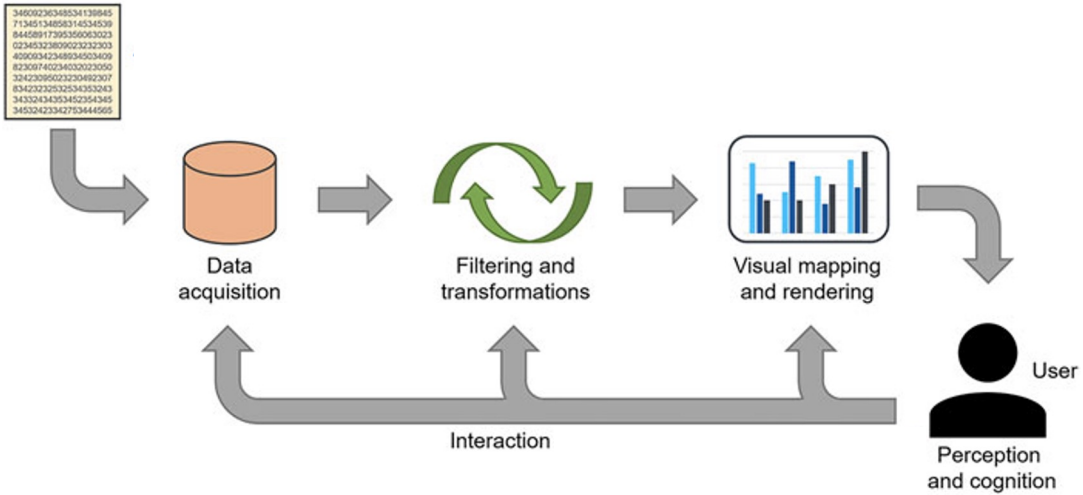
Agenda

1. Navigating uncertainty through visualization
2. Visualization pipeline, i.e., modelling and acquisition, filtering and transformations, mapping and rendering, perception and cognition, and interaction
3. Broad visualization techniques, i.e., graphical annotations and visual encoding methods
4. Cognitive theories underlying visualizing uncertainty with examples (e.g., hypothetical outcome plot and ensemble display)
5. Discussion questions

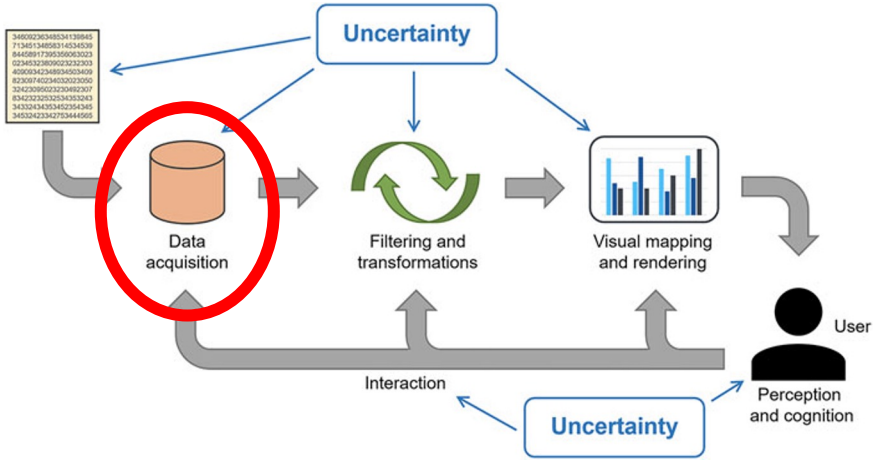
Visualization Pipeline



Weiskopf, 2022

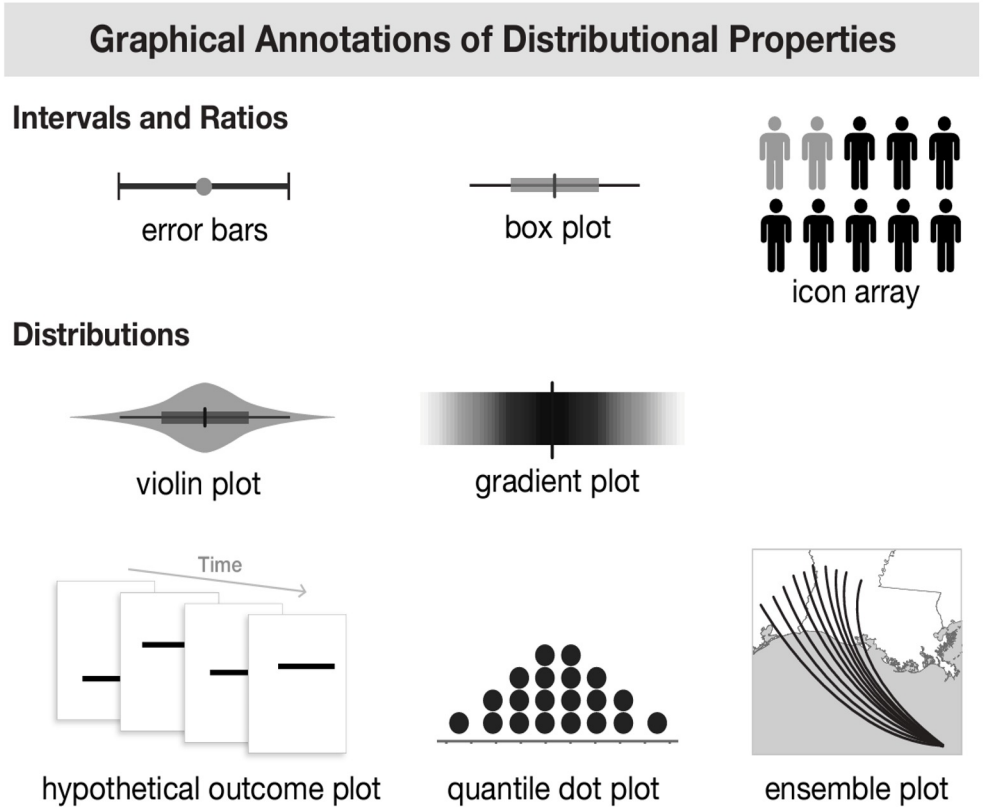
Modelling and Acquisition

- Uncertainty can refer to varying aspects of data, such as error and variability that may impact the quality of the data.
- To understand the type of uncertainty you are visualizing, you must:
  - Understand the source of uncertainty
  - Understand the nature of the uncertainty



Uncertainty visualization technique #1:

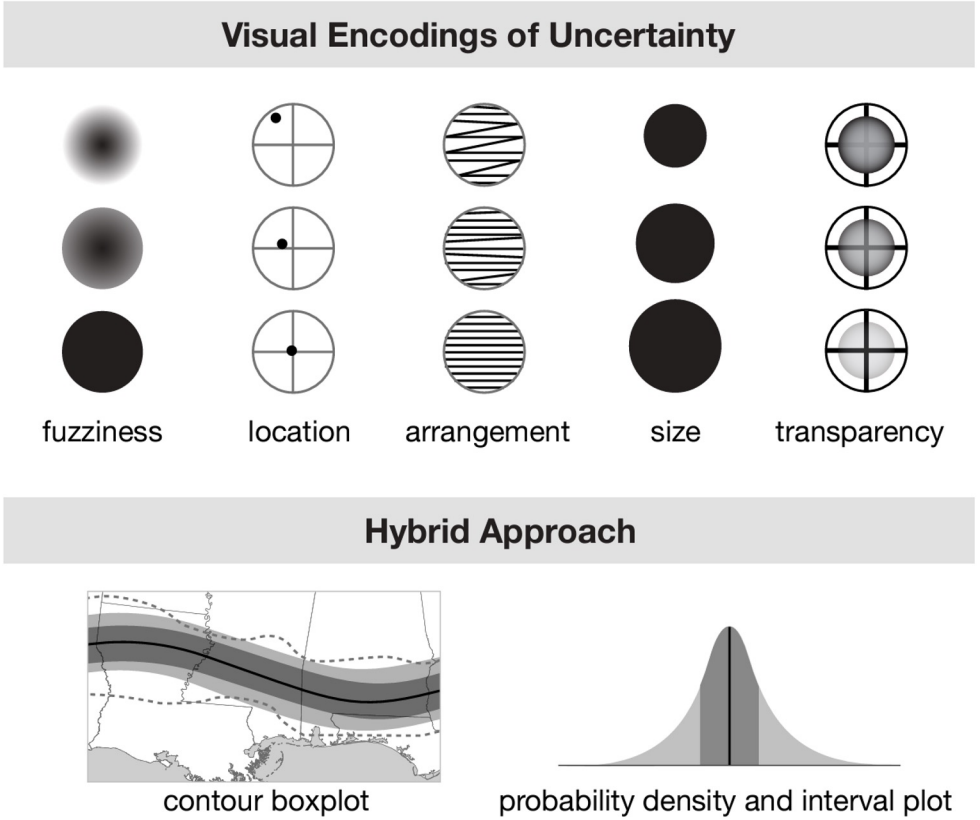
Graphical annotations



Padilla et al., 2020

Uncertainty visualization technique #2:

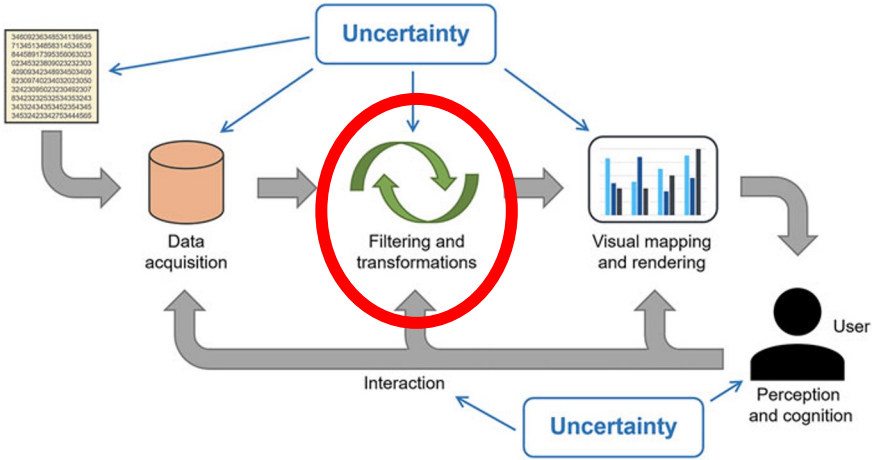
Visual encodings and hybrid approaches



Padilla et al., 2020

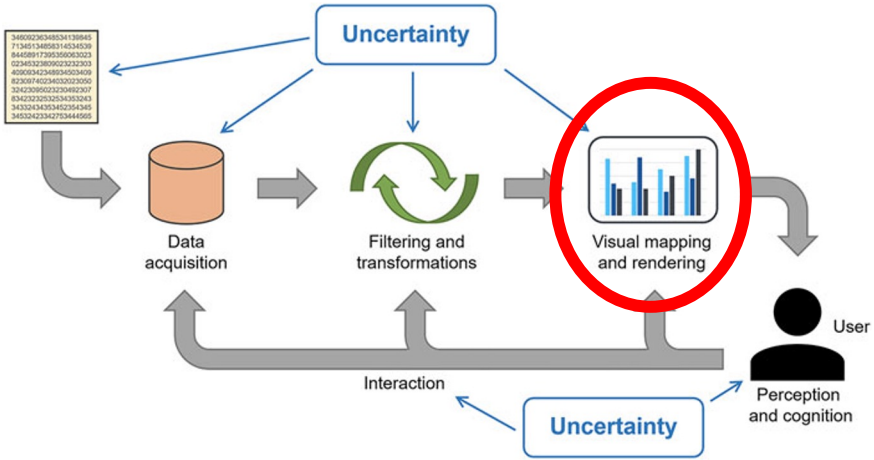
Filtering and Transformations

- Reduce the amount of data shown or simplify the data to reduce its complexity
- Techniques:
    1. Set ranges
    2. Clustering groups adds structure to the data
    3. Reduce dimensionality

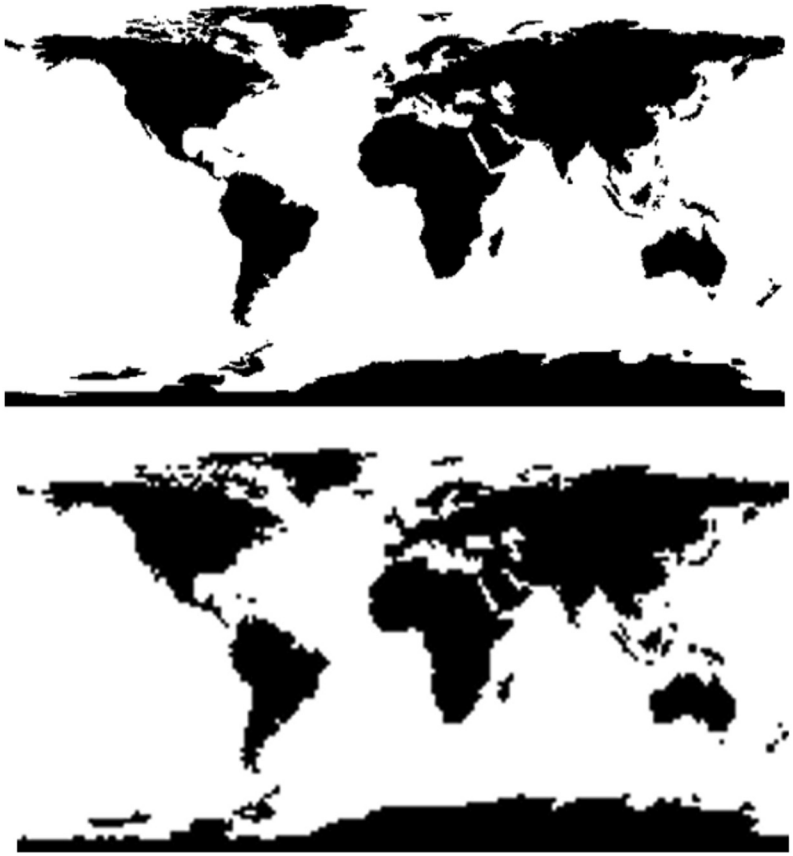


Mapping and Rendering

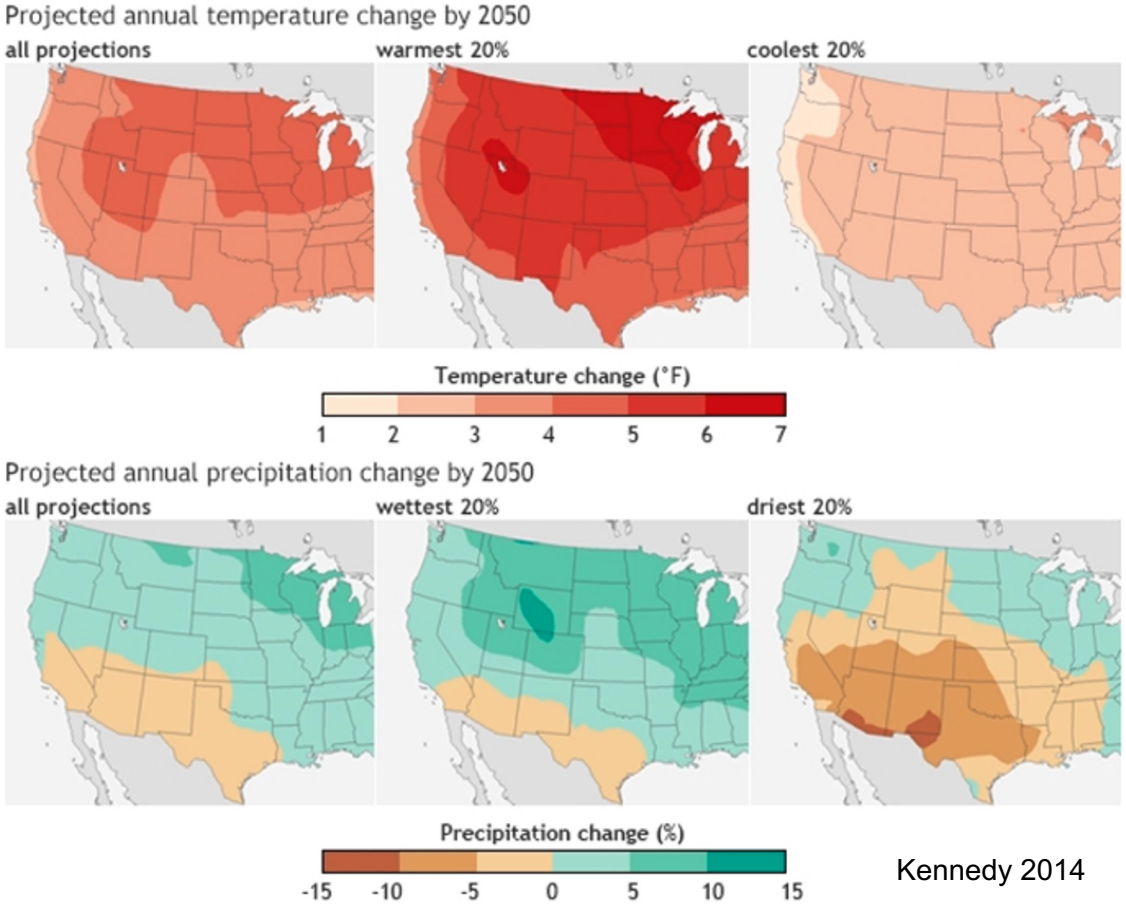
- Transformed data is produced into a representation
- Develop appropriate visual mappings
- Consider variables such as:
  - Colour
  - Opacity
  - Contour crispness
  - Transparency
  - Resolution
  - Geometric attributes



Resolution



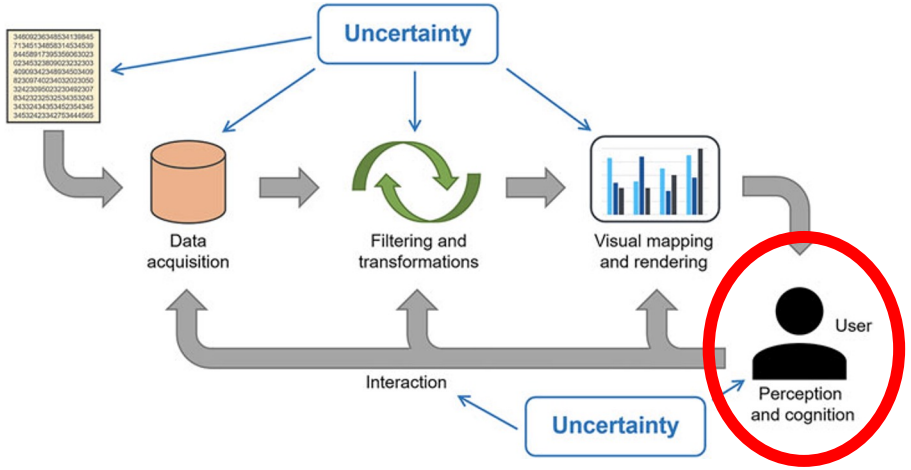
Uncertainty visualizations for future projections



Kennedy 2014

Perception and Cognition

- Design the visualization so that it is understandable by the recipient i.e., consider human factors.
- Caution to convey uncertainty and avoid misinterpretations.

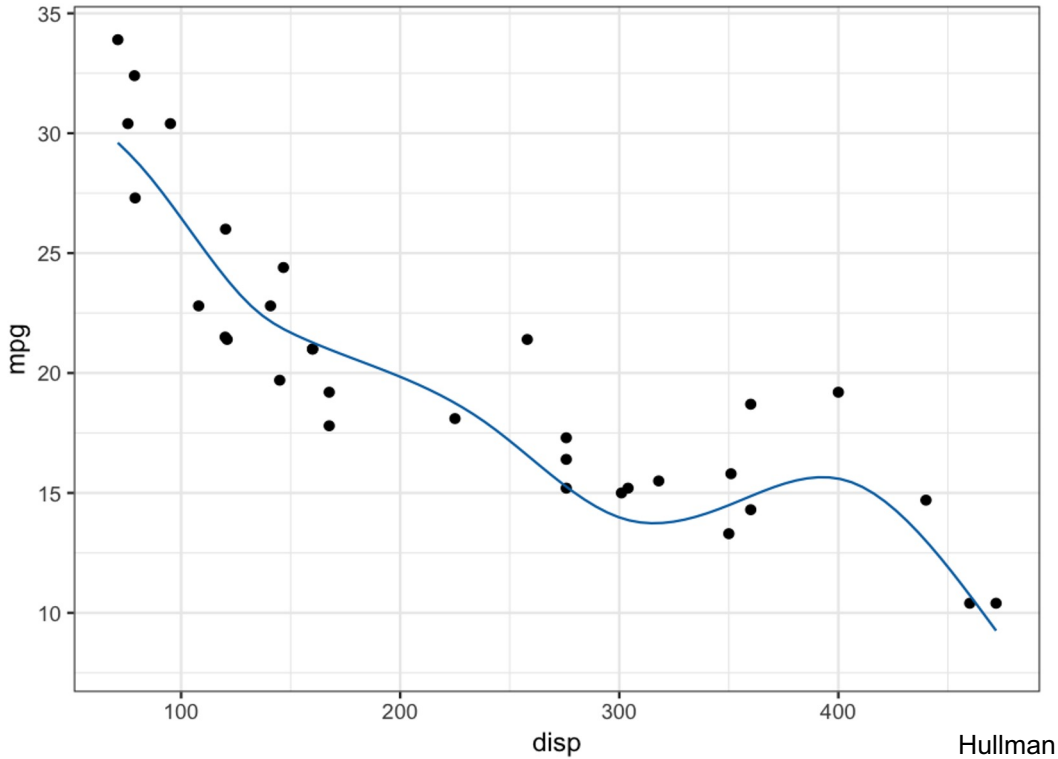


Visualizing uncertainty: Cognitive theories

Theory	Summary	Visualization Techniques
Frequency Framing [30] (Section 1.2)	Uncertainty is more intuitively understood in a frequency framing (1 out of 10) than in a probabilistic framing (10%)	icon array [13], quantile dotplot [11], hypothetical outcome plots [10]
Attribute Substitution [31] - Deterministic Construal Error [32] (Section 1.2)	If given the opportunity, viewers will mentally substitute uncertainty information for data that are easier to understand	hypothetical outcome plots [10]
Visual Boundaries = Cognitive Categories [21] (Section 1.2)	Ranges that are represented by boundaries lead people to believe that data inside and outside the boundary are categorically different	ensemble display [12], error bar alternatives [7, 9]
Visual Semiotics [14] (Section 1.2)	Some encoding techniques naturally map onto uncertainty	fuzziness, transparency, location, etc. [14], value-suppressing color pallet [25]

Padilla et al., 2020

Hypothetical Outcome Plot (HOP)



Hullman et al., 2015

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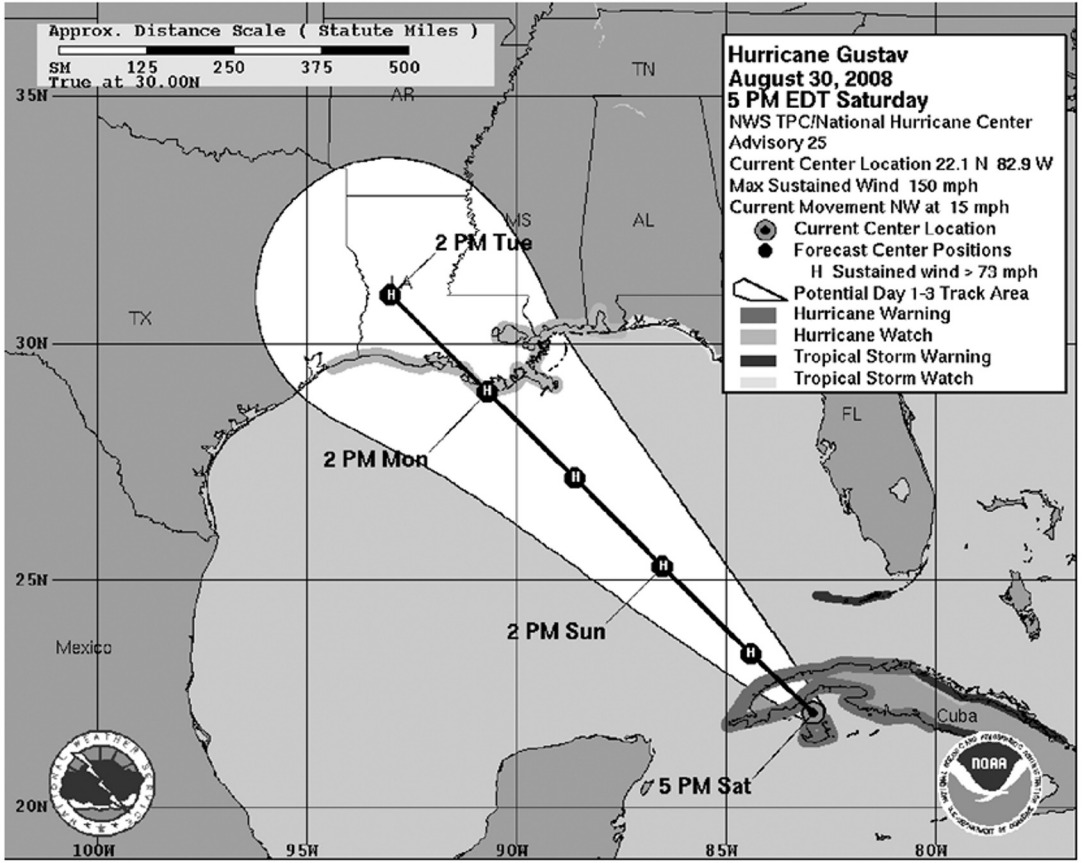
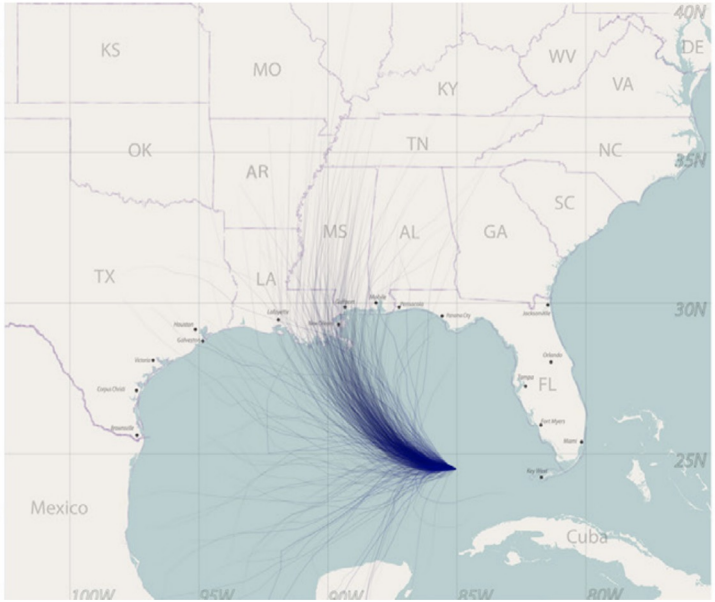
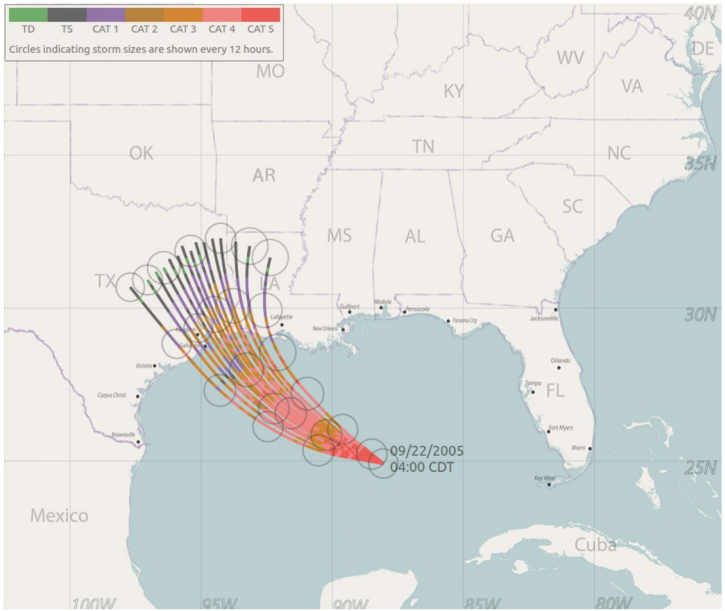
Padilla et al., 2020

Visual boundaries = Cognitive categories



Potential solution: Ensemble display

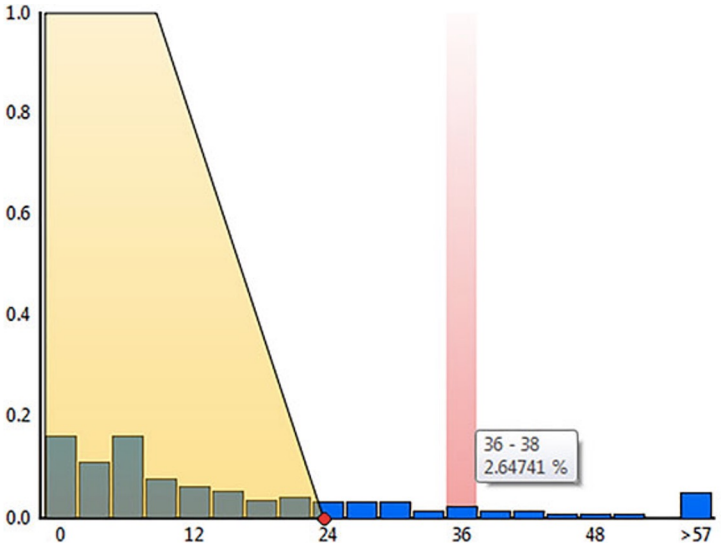


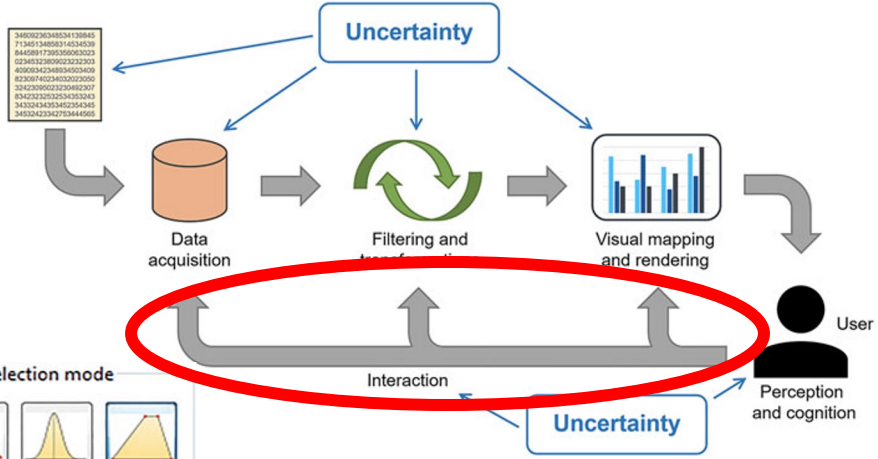


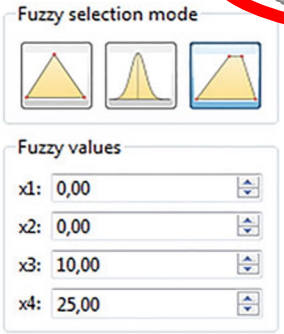
Liu et al., 2015

Interaction

- The user's ability to engage with the visualization







Weiskopf, 2022

Summary & Conclusion

- Uncertainty has a significant impact on visualizations and how recipients perceive and understand the information.
- Uncertainty visualization can be challenging due to the interplay of the different components in the visualization process.
- Cognitive theories play a role in how we perceive uncertainty in visualizations
- Techniques: Visual variables such as colour, opacity, contour crispness, transparency, resolution, and geometric attributes can be used to represent uncertainty along with interactive techniques
- Uncertainty visualizations can have real-world safety implications (i.e., weather forecasting)

Discussion Questions

1. What are some uncertainty techniques that speak to you/do not speak to you?
2. Do you have any personal experience with misinterpreting a graph depicting uncertainty based on the way it was visualized?
3. How can graph designers balance the need for accuracy and precision with the desire for simplicity and clarity in uncertainty visualization?
4. How do cultural or societal factors influence the perception and interpretation of uncertainty in visualization techniques?