Open Questions in Uncertainty Visualization

CScADS Workshop

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July 29, 2010

Advanced Computing and Scientific Data

Jaguar, ORNL

- More bandwidth, storage, & computational power
- Larger data sets:
  - Higher resolutions
  - Longer runs
  - More sophisticated models

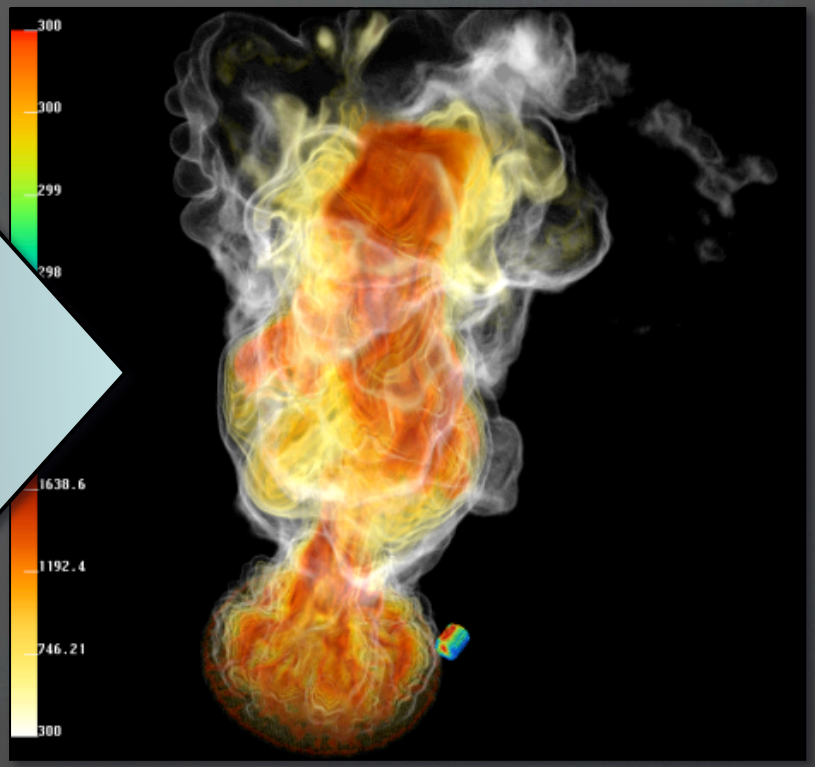
All this leads to huge amounts of complex data

Uncertainty in Data

- Scientific data sets are incomplete without indications of *uncertainty*
- Umbrella term for error, accuracy, confidence level, missing data, inconsistencies, etc
- Multiple definitions depending on field or application
- Fundamental in science, why not in vis?

Visualization is Communication

- Translate data into images, “see” the data
- Brings out relationships & features in data
- Lets scientists communicate within their fields and out to others



Uncertainty Vis is Hard!

- Adding more info to already large data
  - Visual complexity and clutter
  - Can obscure data
  - Increasing visual “uncertainty” can decrease understanding
- What is an appropriate visual metaphor?
- No singular definition, no singular solution

Understanding Uncertainty

- Influential in reasoning, decision making, and risk analysis
- Sources throughout the scientific process: acquisition, transformation, sampling, quantization, interpolation, classification, visualization…
- Provenance of uncertainty important in understanding

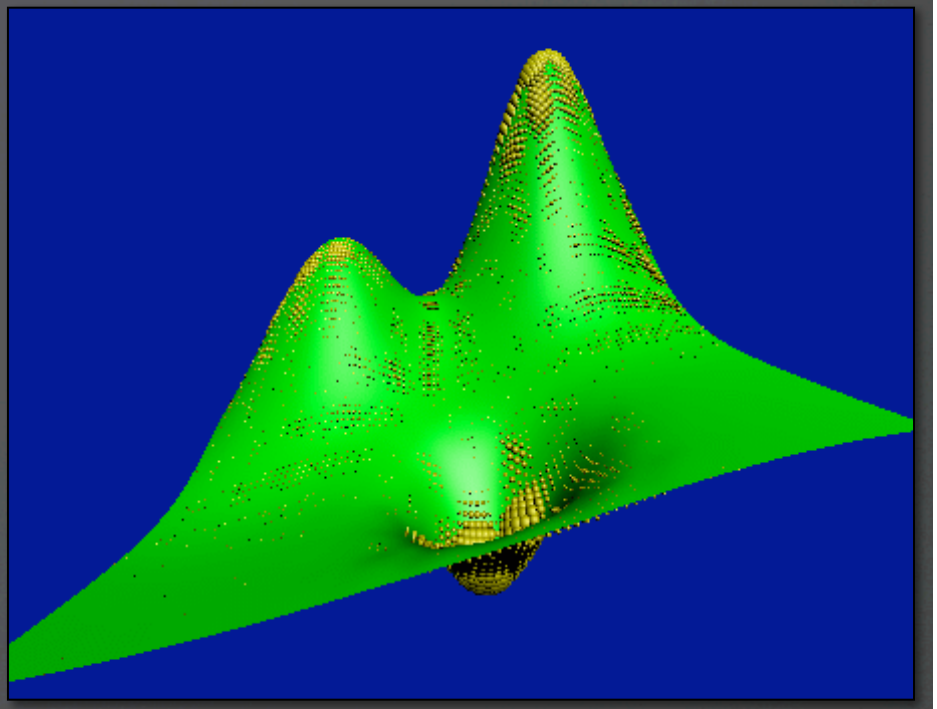
Types of Uncertainty

- Experimental Uncertainty
  - NIST defines uncertainty as standard deviation of a measurand*
- Geometric Uncertainty
- Simulation Uncertainty
- Visualization Uncertainty

* Barry N. Taylor and Chris E. Kuyatt.
Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results.
NIST Technical Note 1297, 1994.

Types of Uncertainty

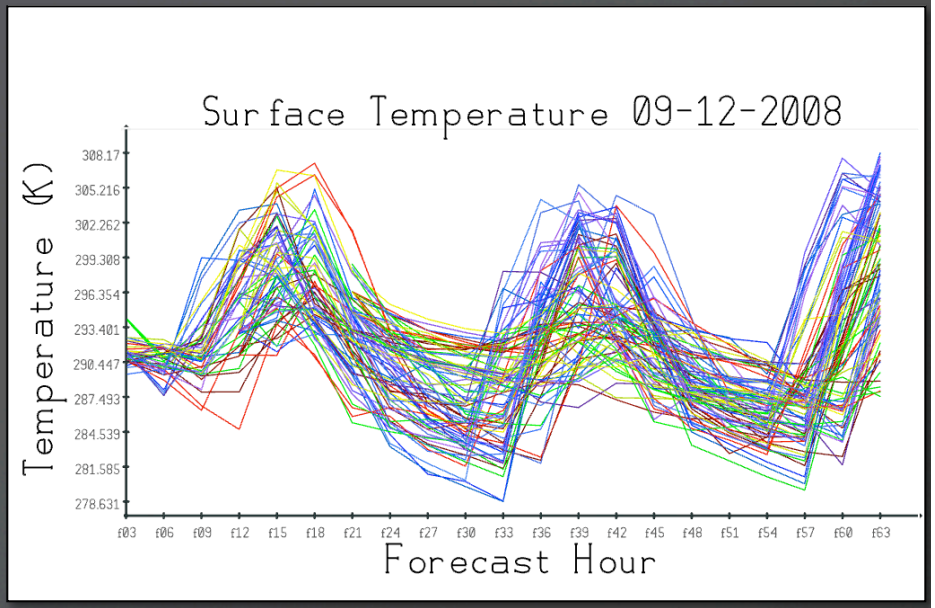
- Experimental Uncertainty
- Geometric Uncertainty
  - Unknowns in spatial positions
- Simulation Uncertainty
- Visualization Uncertainty



* S. Lodha, B. Sheehan, A. Pang and C. Wittenbrink.
Visualizing Geometric Uncertainty of Surface Interpolants
In *Proceedings of Graphics Interface '96,* pp. 238--245. 1996.

Types of Uncertainty

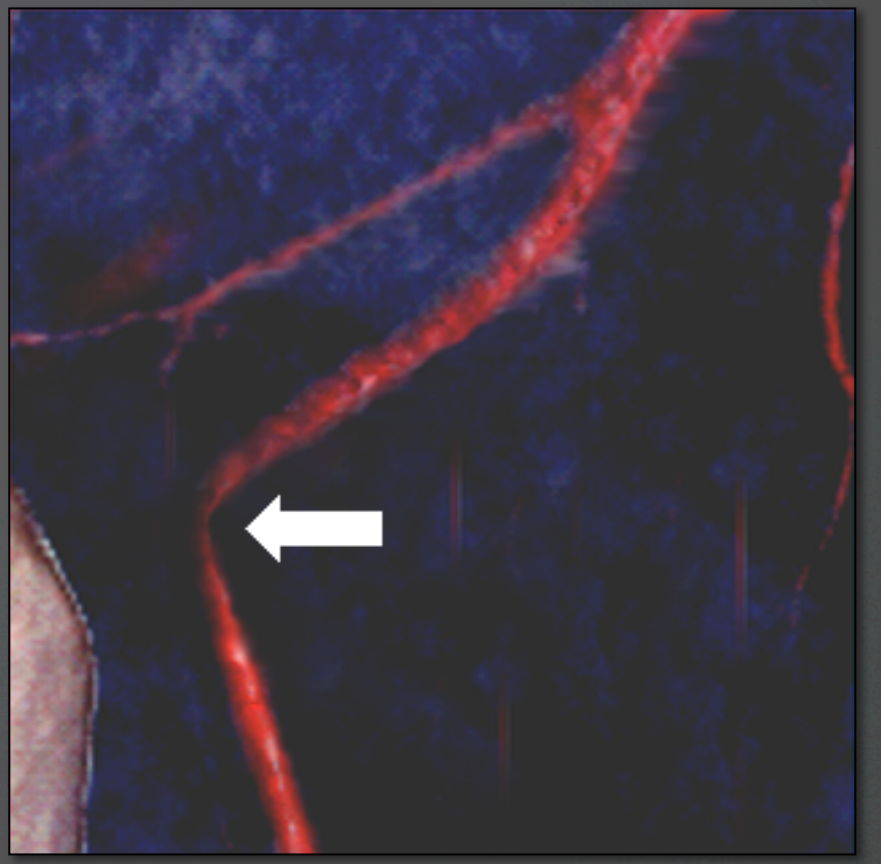
- Experimental Uncertainty
- Geometric Uncertainty
- Simulation Uncertainty
  - Multimodel, ensembles or non-determininistic
- Visualization Uncertainty



* K. Potter, A. Wilson, P.T. Bremer, D. Williams, C. Doutriaux, V. Pascucci, C. Johnson Ensemble-Vis: A Framework for the Statistical Visualization of Ensemble Data. In *IEEE Workshop on Knowledge Discovery from Climate Data,* pp. 233-240, 2009.

Types of Uncertainty

- Experimental Uncertainty
- Geometric Uncertainty
- Simulation Uncertainty
- Visualization Uncertainty
  - Parameters of technique lead to differences



* C. Lundström, P. Ljung, A. Persson, and A. Ynnerman,
Uncertainty Visualization in Medical Volume Rendering Using Probabilistic Animation,
In *IEEE TVCG*, 13(6,) pp. 1648-1655, 2007,

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Uncertainty Visualization

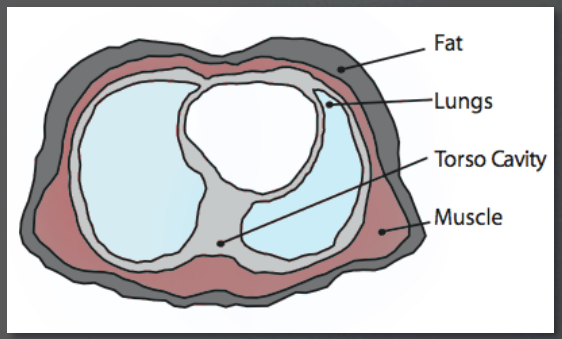
- Visually depict uncertainties
- Faithfully present data
- Improve vis as a decision making tool
- Top visualization research problem *

* Chris R. Johnson.
Top Scientific Visualization Research Problems,
In *IEEE CG&A* 24(4) pp. 13--17, 2004.

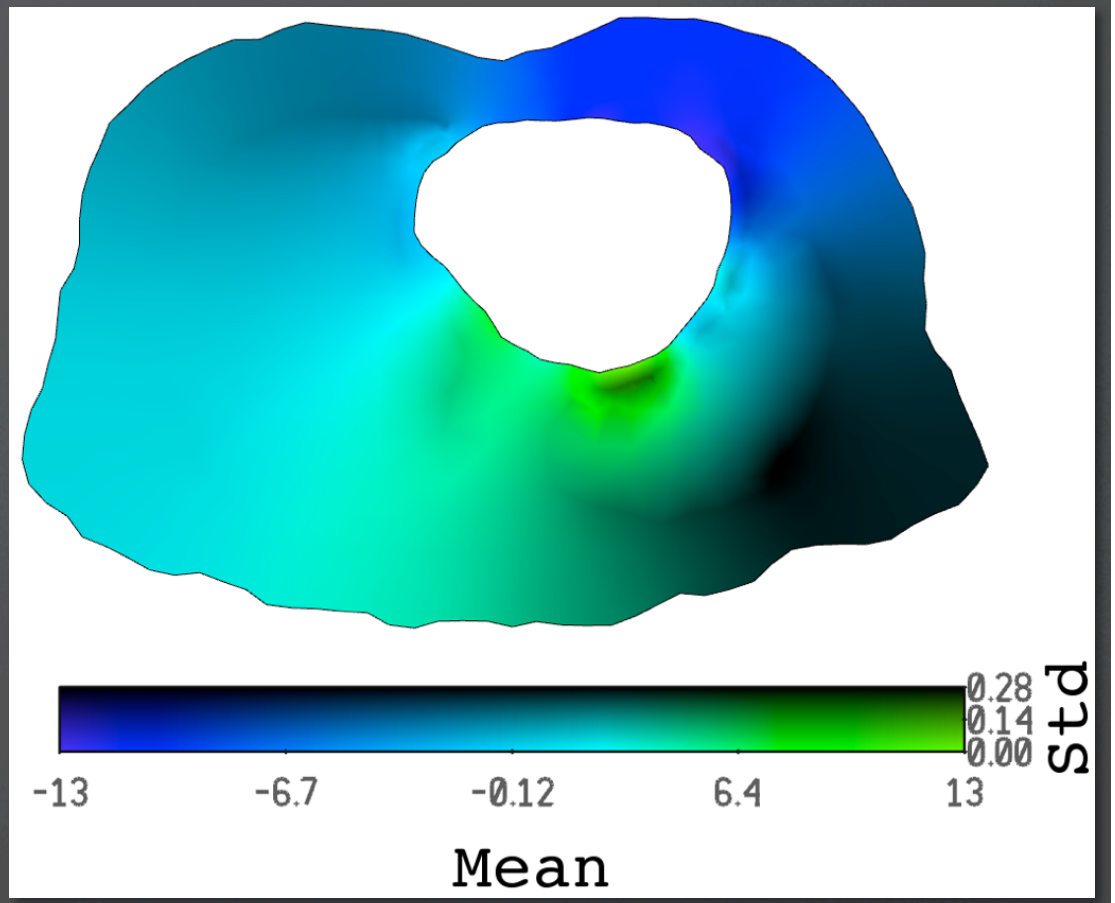
Approaching the Problem

- What is the nature of the uncertainty?
- Is it a primary or secondary attribute?
- Does the visualization design agree with the data characteristics?

Sensitivity-Type Analysis

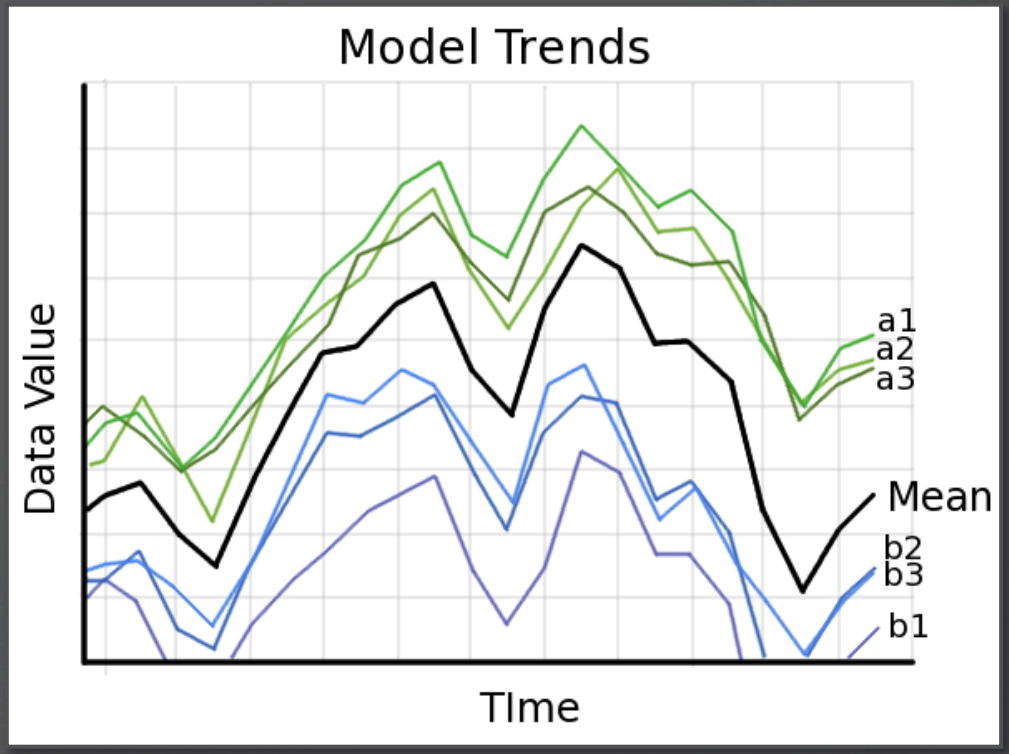


- Input perturbations reflected in output
- Sensitivity of parameters
- Location & magnitude of variation important



Multi-Model Ensemble Runs

- Collection of models predicting the same variable, time step, location
- Uncertainty in the variation of the models
- Standard deviation may not fully describe uncertainty



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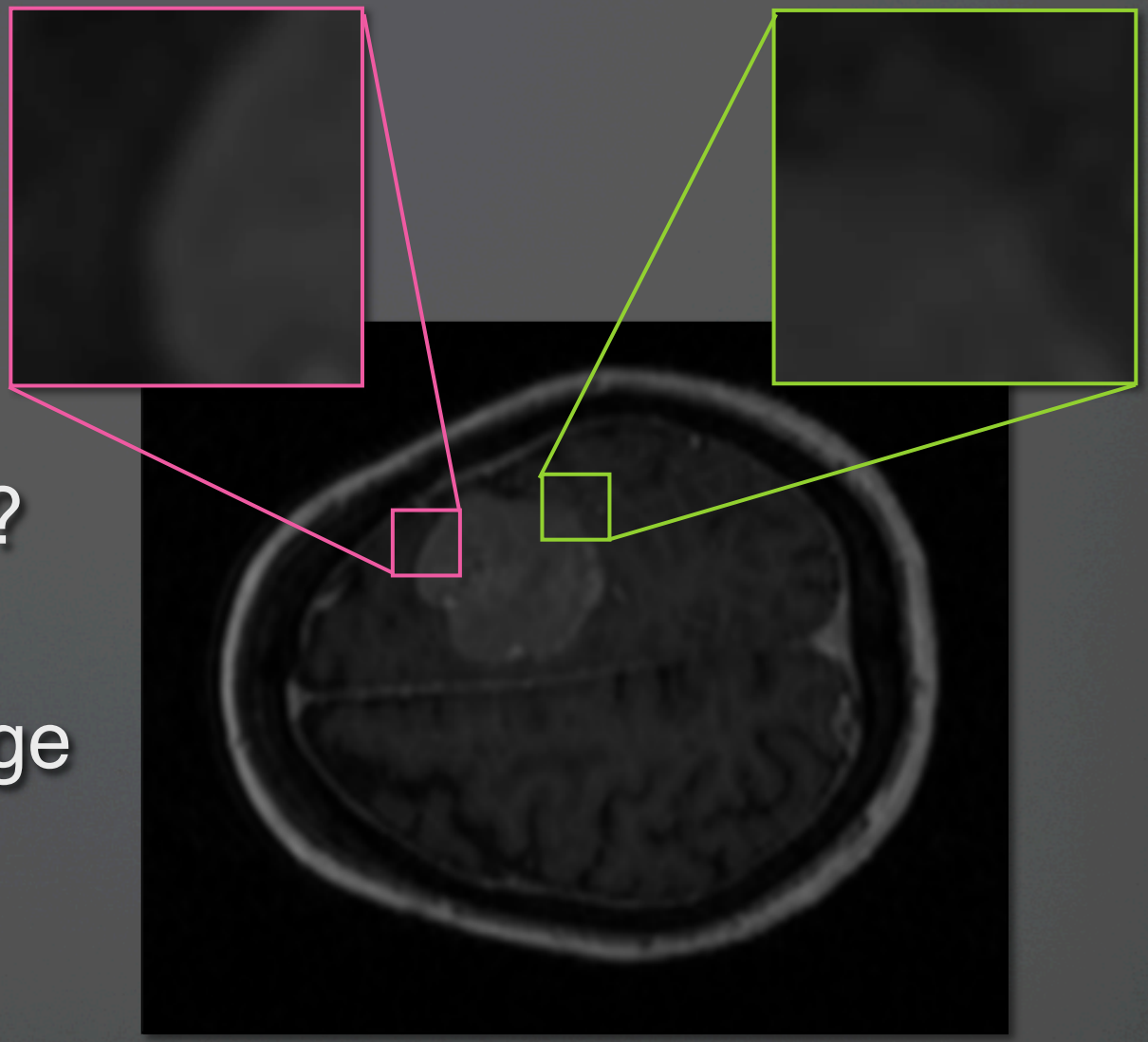
Primary Uncertainty

- Top-level information
- Where is the surface location?
- What is the boundary or range between tissue types?



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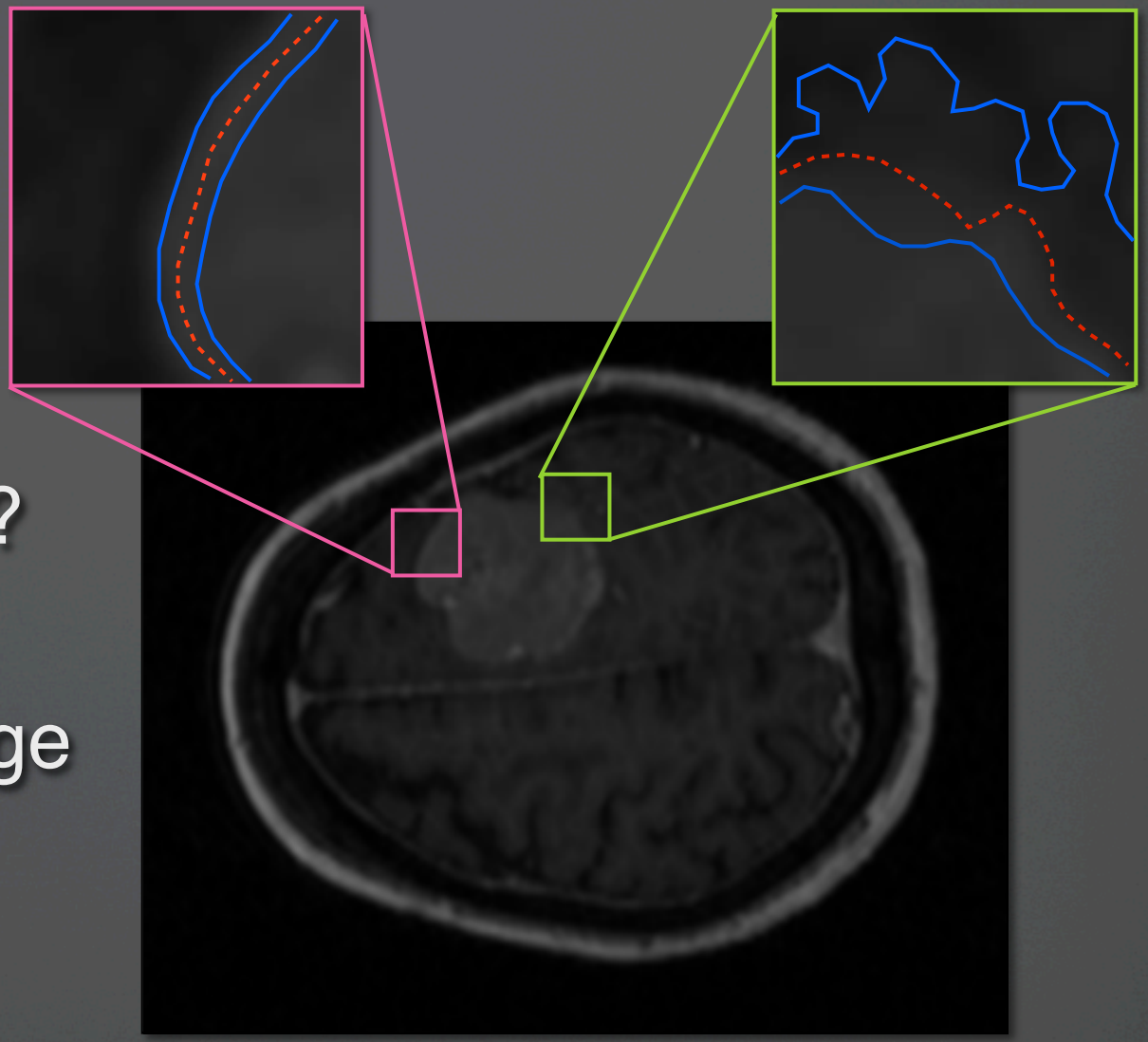
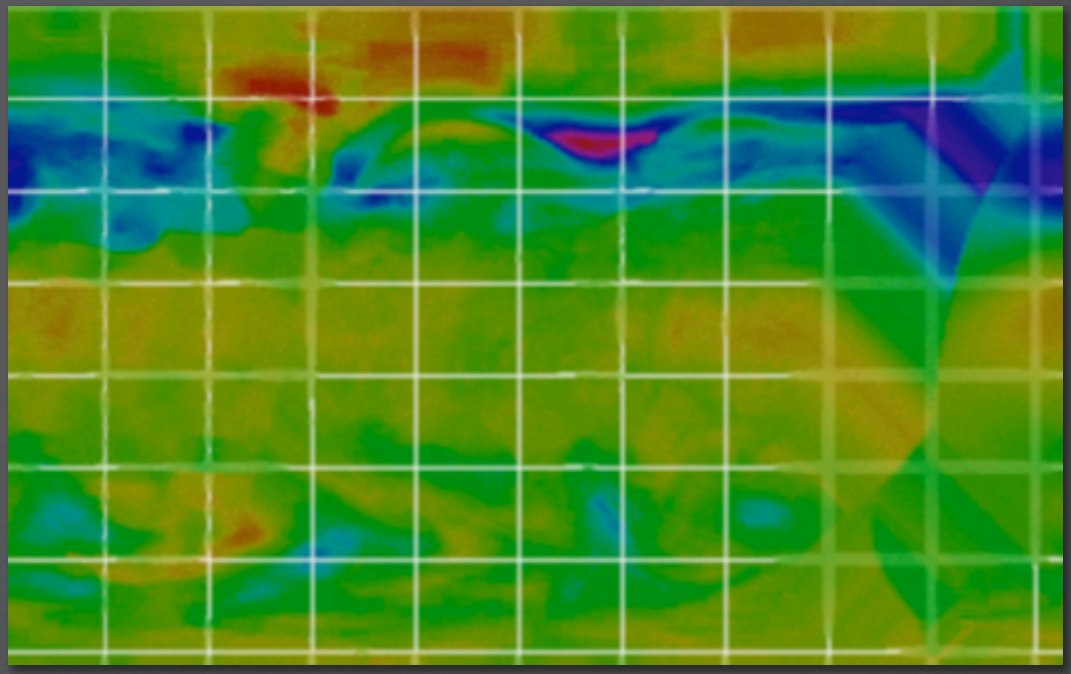


Secondary Uncertainty

- Annotation lines indicate missing data
- Minimal interference
- No extra emphasis on uncertain areas



* Andrej Cedilnik and Penny Rheingans.
Procedural Annotation of Uncertain Information.
In *Proceedings of Vis '00,* pp. 77--84, 2000.

Approaching the Problem

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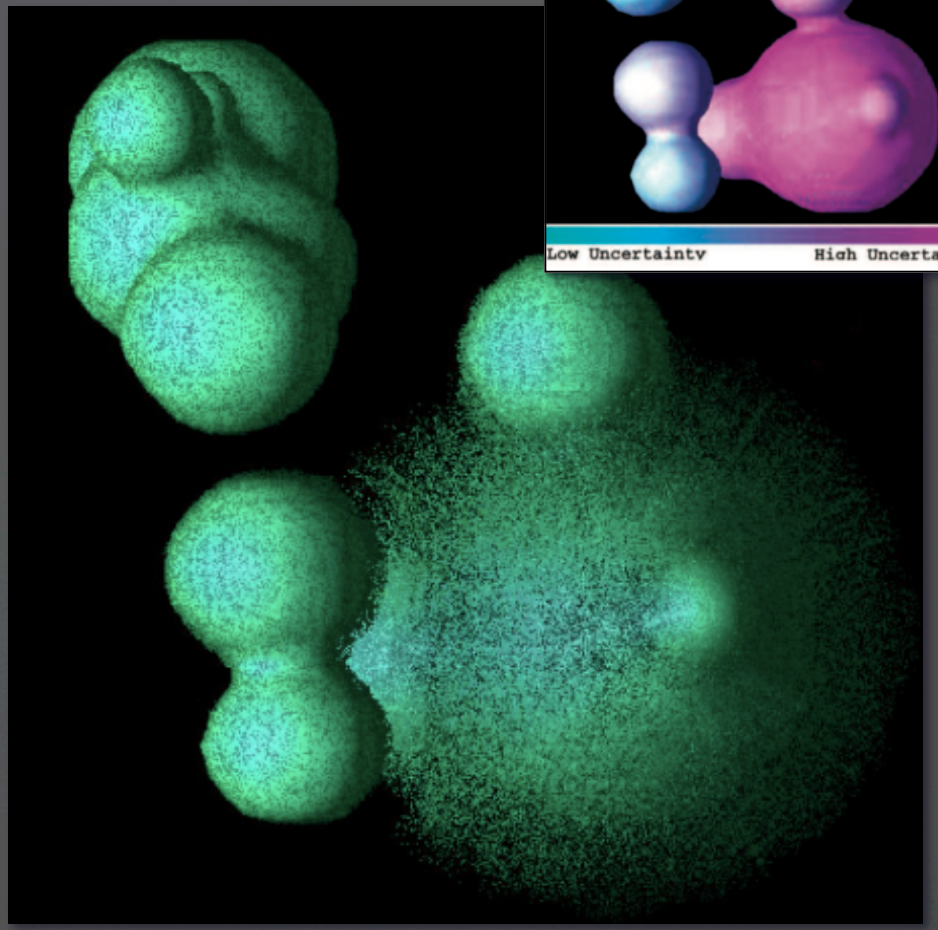
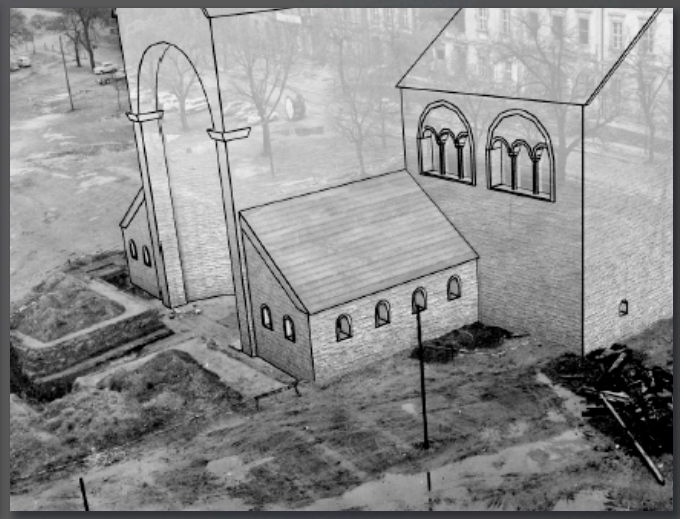
Uncertainty as a Scalar Value

- Clear visual metaphor
- People can interpret blur and fuzz as uncertainty
- But they cannot **quantify** the amount of uncertainty from blur



* Gevorg Grigoryan and Penny Rheingans.
Point-Based Probabilistic Surfaces to Show Surface Uncertainty
In *IEEE TVCG*, 10(5), pp. 546--573, 2004.

The Problem of Pretty Vis



- Reconstruction of medieval architecture
- Shiny pictures, solid lines indicate truth
- Sketchiness, opacity convey uncertainty

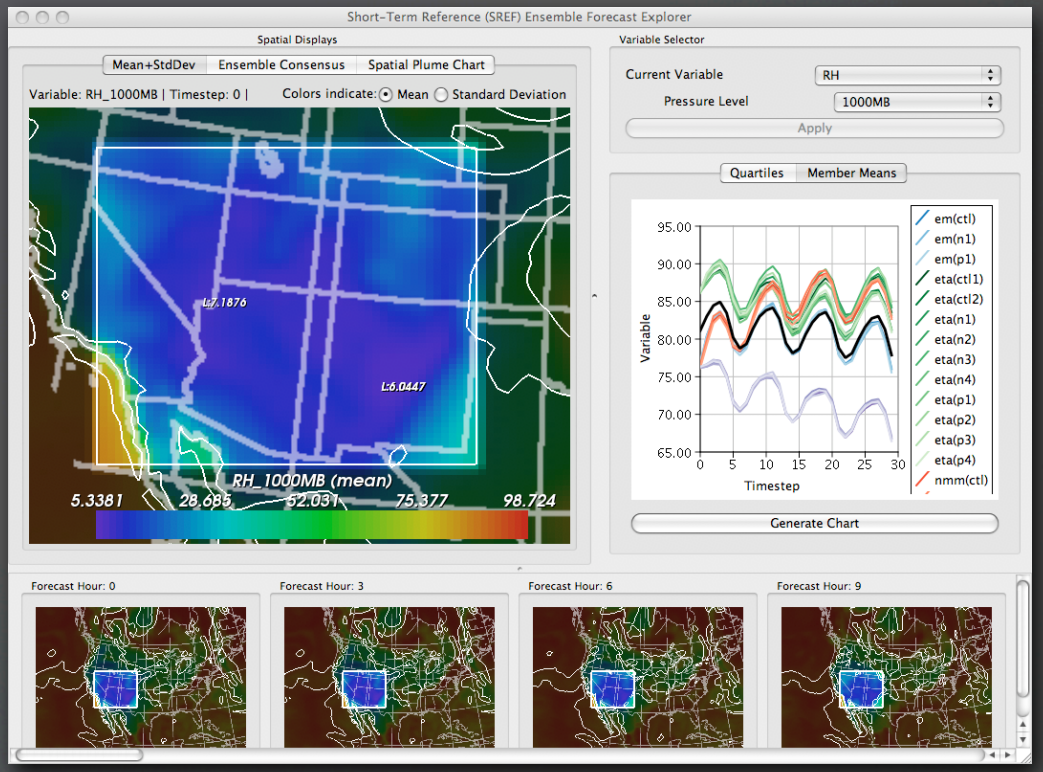
* Thomas Strothotte and Maic Masuch and Tobias Isenberg.
Visualizing Knowledge about Virtual Reconstructions of Ancient Architecture.
In *Proceedings of Computer Graphics International*, pp. 36--43, June, 1999.

Solutions?

- Simplfication:
  - summarization, feature detection, dimension reduction
- Interaction:
  - drill-downs, linked views, small multiples
- Flexibility:
  - use the right display for the right data

Ensemble-Vis

- Multiple linked displays
  - user driven analysis
- Summary overviews
  - colormaps & contours
- Drill down
  - 2D charts, direct data display



What about evaluation?

- Missing for visualization in general
- Typically user surveys, expert assessment, anecdotal judgement
- Influenced by personal preferences, user experience, cultural biases, resistance to change

Better methods needed for ALL Vis!

Take Home

- Qualitative information essential
- Design should reflect sources, types, & importance in application
- Evaluation methods sorely needed

Each problem is unique & different:
general approaches can only get you so far!

Thanks!

Questions?