Geographical Uncertainty
Why it is difficult to present and judge

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Issues in Geographical Uncertainty

The following are difficult topics:

- uncertainty
- probability models of uncertainty
- probability models of spatial uncertainty
- probability models of spatial-temporal uncertainty
- communicating uncertainty
- communicating geographical uncertainty

Uncertainty is difficult

- Epistemological vs. Aleatory
- Ambiguity
  - What do I or we mean?
    - Need to think, modelling will not help
  - What does he mean?
    - Communication issue
- Deep uncertainty
  - Knightian or strict uncertainties
  - Impossible to model probabilistically?
  - Or simply too much disagreement on the values of probability?
- Opposite of knowledge
  - Knowledge Management
  - Cynefin
  - Believe in the model; mishandle the emergench

Probability is difficult

- Try teaching it!
- What does probability mean?
  - Relative frequency
  - Subjective: degrees of belief
  - Other interpretations, e.g. logical/linguistic
- The mathematics becomes non-trivial pretty quickly
  - And computationally difficult too
- Most textbooks assume probabilistic independence everywhere
  - Life does the opposite!
  - We cannot learn without probabilistic dependence

Spatial Uncertainty is difficult

- What does
  "The probability of rain in Reykjavik tomorrow is 0.95"
  mean?
- Spatial distributions are dependent
  - Usually neighbouring points have similar values
- Uncertainty at a point:
  - What's there? Properties/composition?
- Uncertainty of a boundary
  - Where is it? What does it bound/separate? Hard/soft?
- So spatial inference is hard
  - Hunter and Beard (1992) recognised over 150 possible sources of error/uncertainty when dealing with spatial data.

Spatial-temporal uncertainty is difficult

- Things move over time
- Data does not necessarily become available in a simple way relative to the movement of objects
- Temporal queries in databases are hard, much harder than in GIS and relational/object databases

Communicating uncertainty is difficult

- Difficult to scientists; more difficult to lay public
  - And **DECISION MAKERS!!!**
- System 1 vs System 2 thinking
  - System 1: subconscious intuitive interpretation of and reaction to uncertainty
  - System 2: analytic explicit modelling
- Cultural dimension
  - Uncertainty: Wright and Philips (1980)
  - Geographical: Walsham and Sahay (1998)
  - Mapping conventions
- However, there has been much work on the effective communication of uncertainty and risk away from the spatial-temporal domain

It follow that ….

- Judging and communicating geographical uncertainty is real fun!!!
  - MacEachren (*et al!*) have continually advised me that it is right at the research front of cartography and GIS research worldwide.
  - A. M. MacEachren, *et al* (2005). "Visualizing geospatial information uncertainty: what we know and what we need to know." *International Journal of Geographic Information Science* ***32(3): 139-160.***

MacEachren et al (2005) Challenges

1. Understanding the components of uncertainty and their relationships to domains, users, and information needs
2. Understanding how knowledge of information uncertainty influences information analysis, decision making, and decision outcomes
3. Understanding how (or whether) uncertainty visualization aids exploratory analysis
4. Developing methods for capturing and encoding analysts' or decision makers' uncertainty
5. Developing representation methods for depicting multiple kinds of uncertainty
6. Developing methods and tools for interacting with uncertainty depictions
7. Assessing the usability and utility of uncertainty capture, representation, and interaction methods and tools

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- But judging and communicating geographical uncertainty is what experts have to do in many government and business contexts
  - Spread of disease or contamination
  - Travel patterns
  - Geology deep underground for GDS
  - Volcanic eruptions
  - …

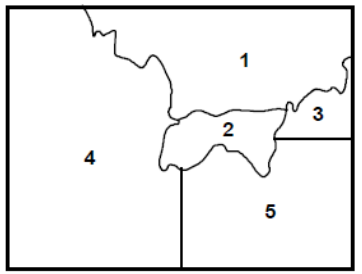
Problems with displaying Geographical Uncertainty

- Displaying location uncertainty may/will enlarge the visual impact and hence the apparent seriousness of what is displayed
- Information overload: maps are already very busy with information.
  - 'Solved' by heavy reliance on agreed conventions and symbols
- Adding location, quantity, temporal, etc. uncertainty to any of this information increases the amount of information to be absorbed
  - No agreement (yet) on conventions and symbols
  - Probably need to strip out much of the other information on the maps to make way for that on uncertainties – easy in principle, not so much in practice.

Possible conventions for showing uncertainty

[Note: cartographers and geographers are seldom expert in uncertainty concepts so to some extent are re-inventing the literature on uncertainty per se – and often in a different language!]

- Static: size, colour/shade/density, blurring, transparency, annotating with a numeric probability, probability contours, hot/cold shading, ….
- Animation: feathering/vibration/blinking
- Reliability diagrams (source of information)
  - What information is the diagram conditional on?
- Sound: different levels of white noise as cursor moves



Transparency of Methods for new users

- Experience to date relate more to computer graphics experiments than evaluated methodologies
- While the results might be encouraging with the ‘cognoscenti’ involved in their development and extensively trained in their use, few methods are intuitive or transparent to new users.
- In short, we currently lack the tools for working with (most) experts and decision makers

Eliciting expert judgement on geographical uncertainty?

- Difficult without an agreed convention for displaying the uncertainty
  - You need a language in which to ask the question
  - So question structure will be *very* context specific
- Remember the difficulty in being clear about *what* spatial-temporal probability or probability distribution we want
  - Will need to be more precise and clear on questions and conditioning information.
- It is likely that the elicitation will take longer than for non-geographical contexts
- In some circumstances, one can ask experts for their uncertainty over parameters in spatio-temporal models
  - But that means that we are asking about non-observables

Key questions we have to address

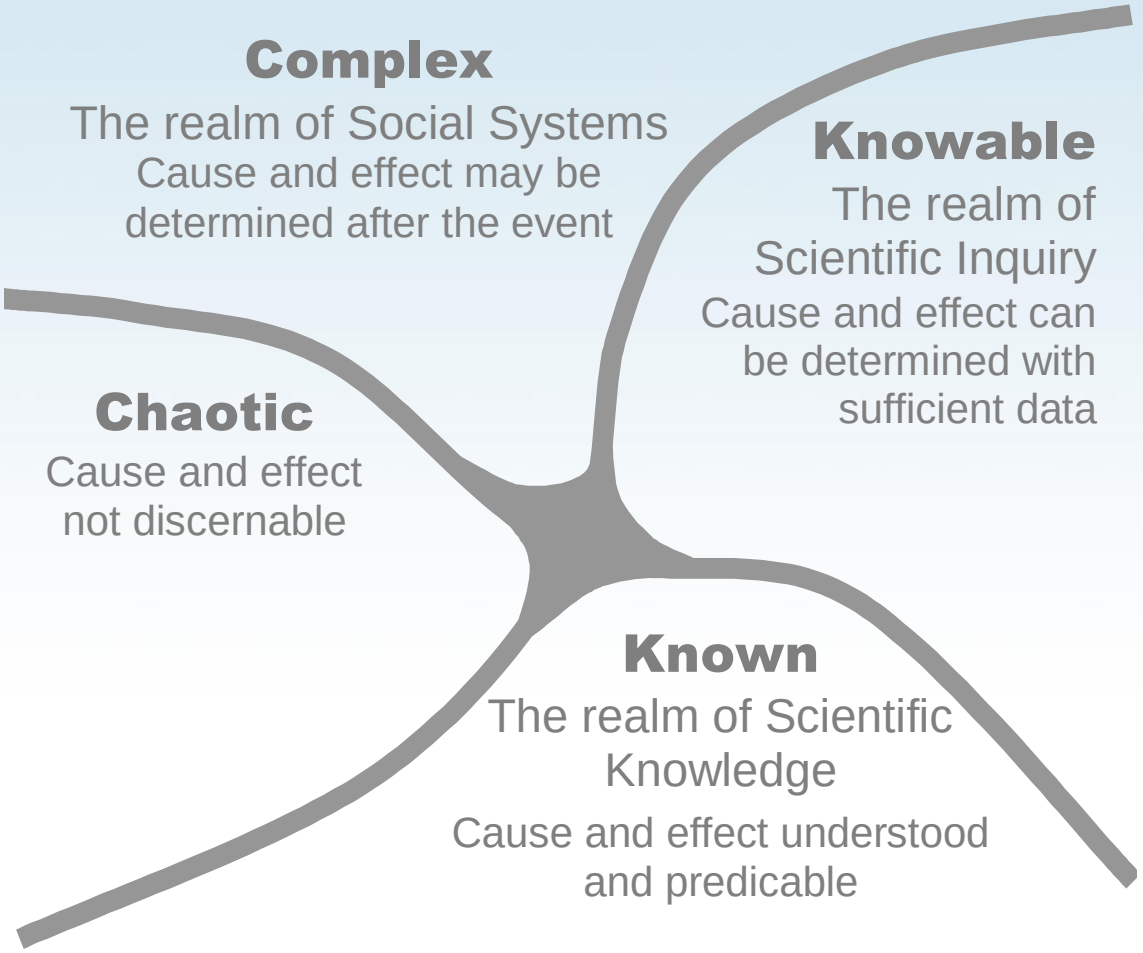
- Who needs the information/uncertainty bounds?
- Why do they need it?
- What information/uncertainty bounds are we going to give them?
  - What do we think we need give them?
  - What do they think that we are giving them?
- How are we going to present the uncertainty?
- Who will be liable in court?

Thank you

Cynefin: a Welsh habitat

Cynefin:

- physical environment
- cultural environment
- social environment
- historical environment
- …..



D. Snowden (2002). "Complex acts of knowing - paradox and descriptive self-awareness." *Journal of Knowledge Management* **6** pp. 100-11.

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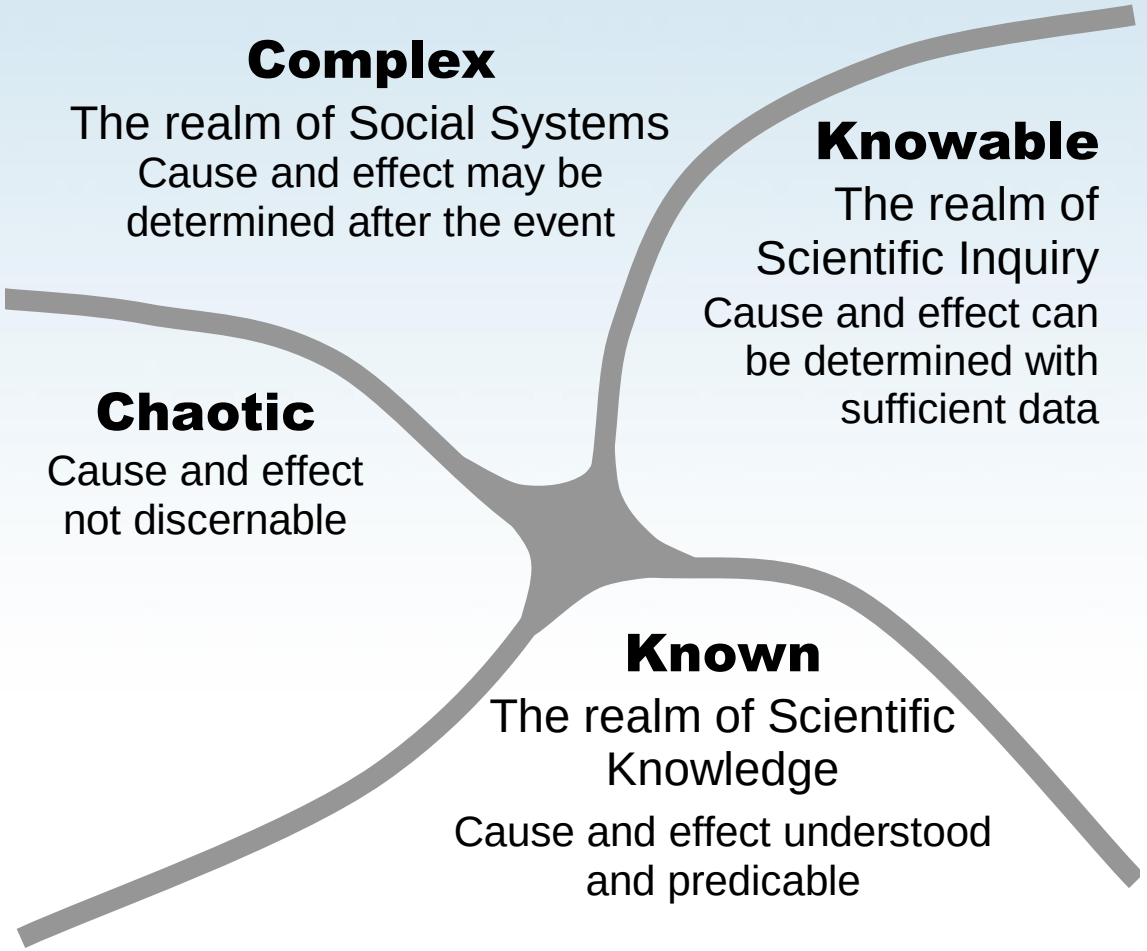

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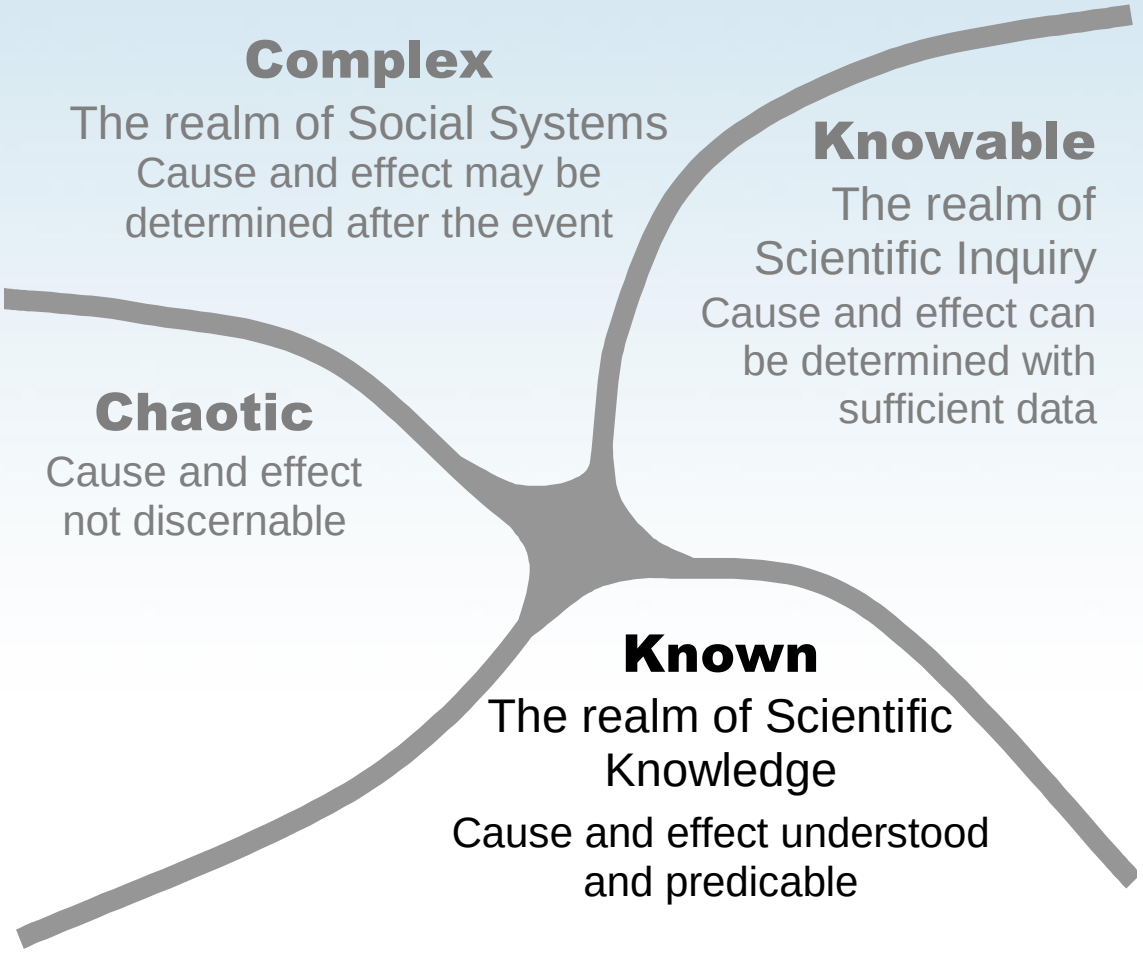

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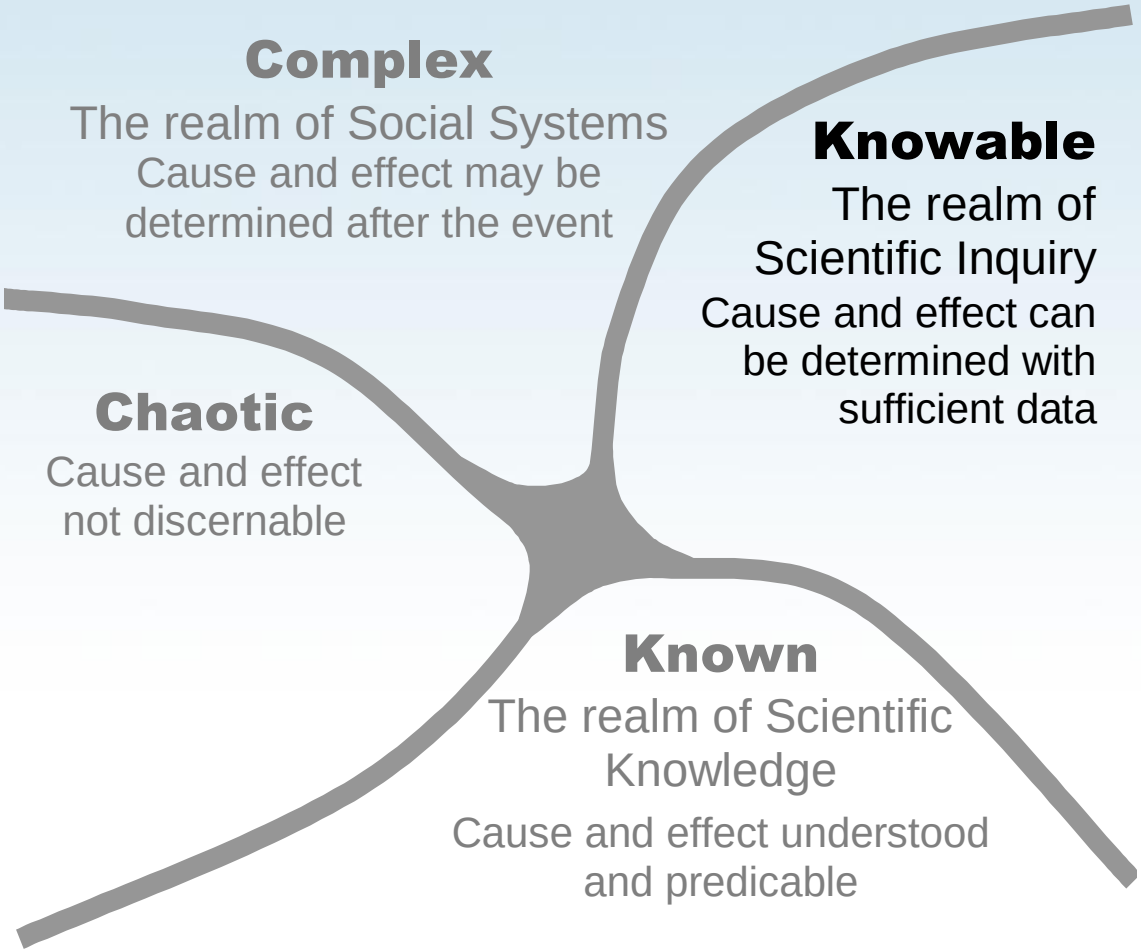

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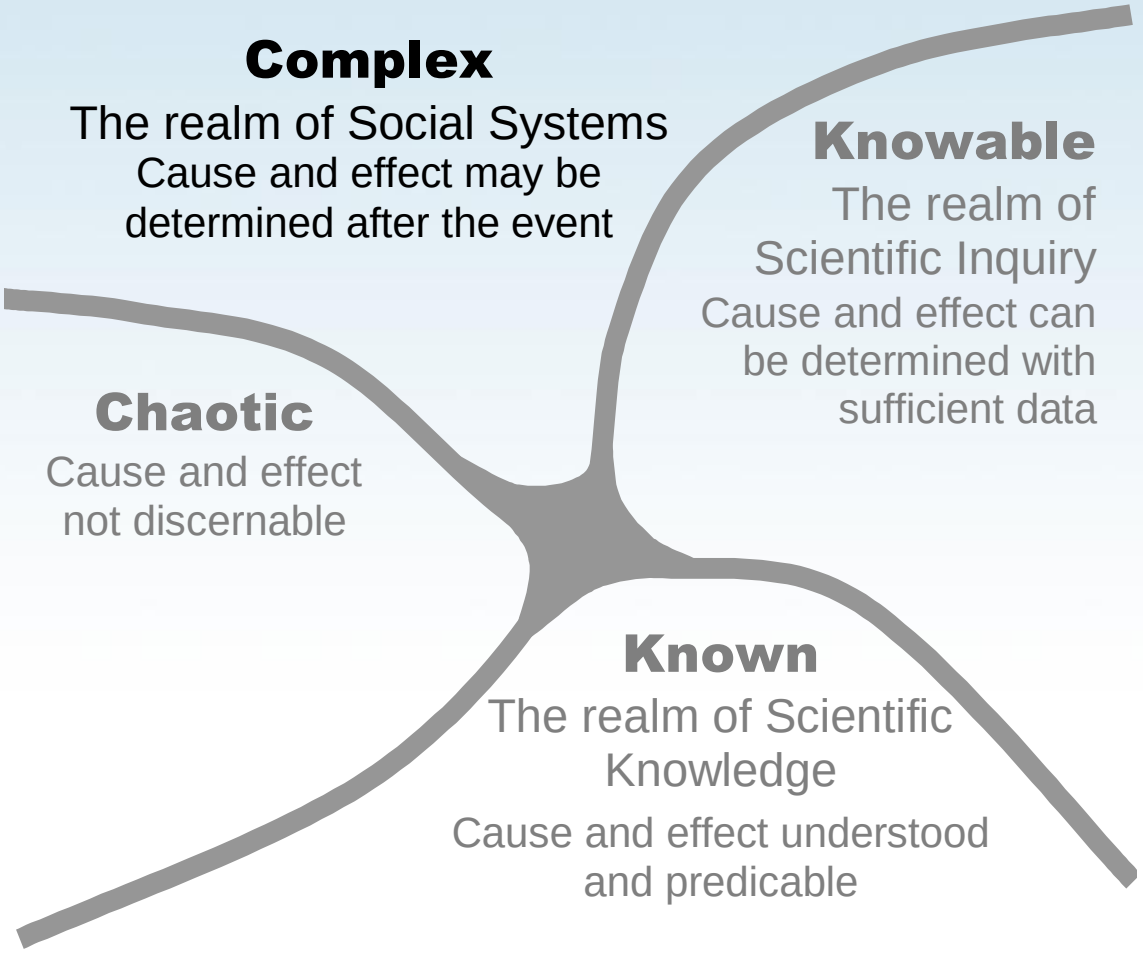

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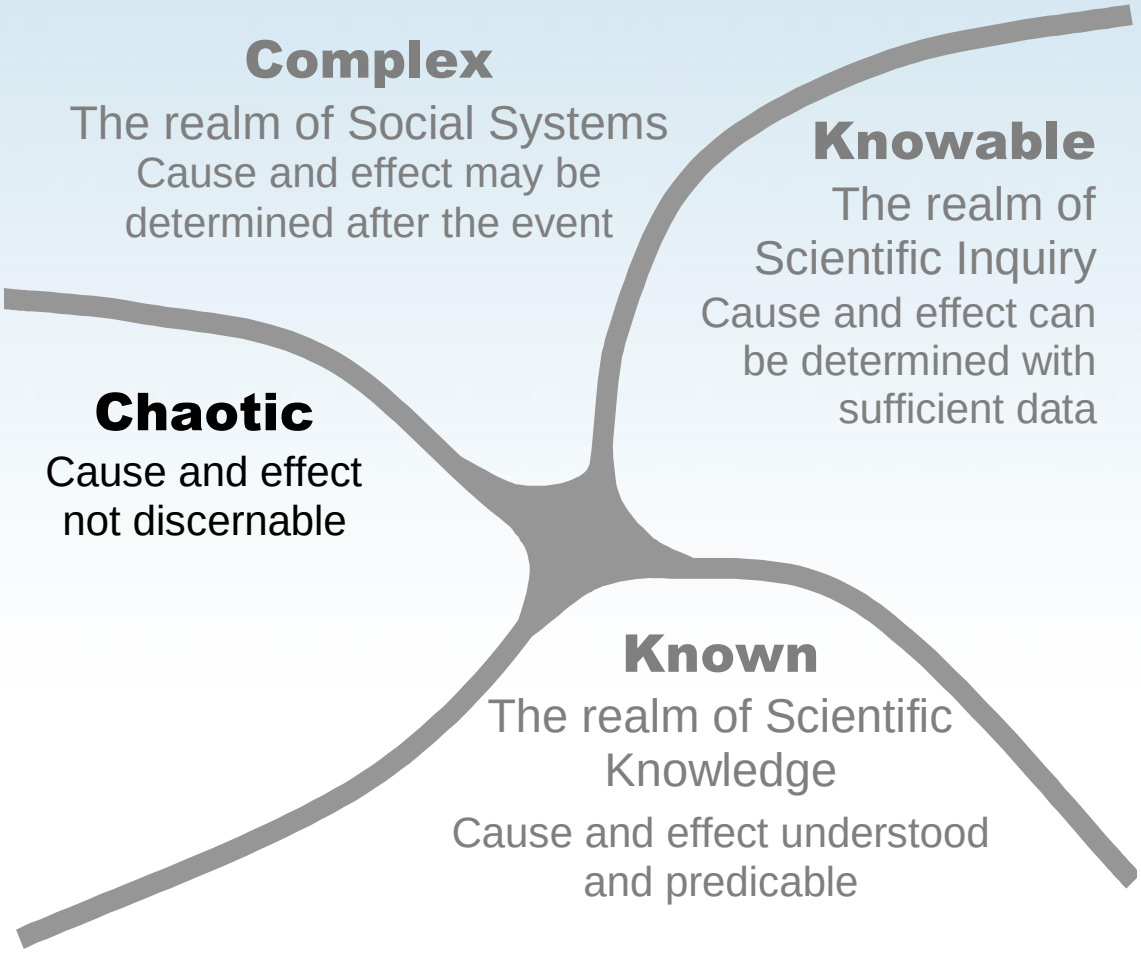

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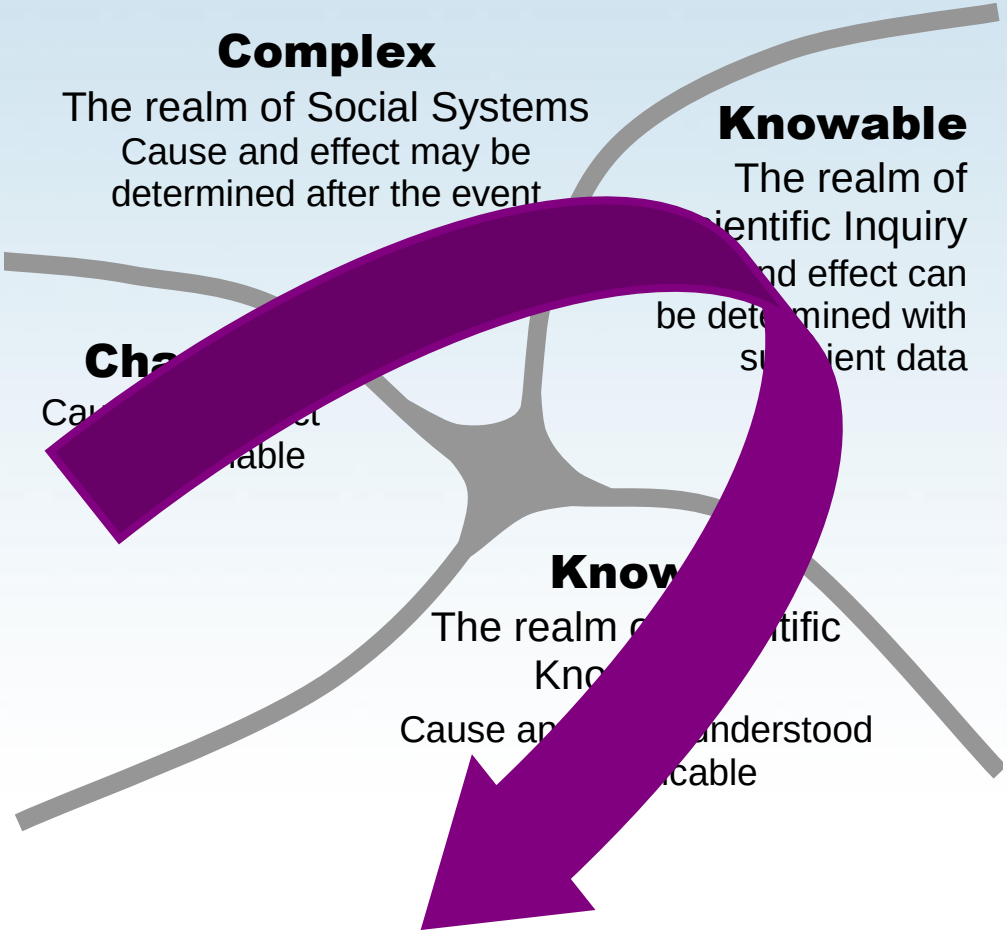
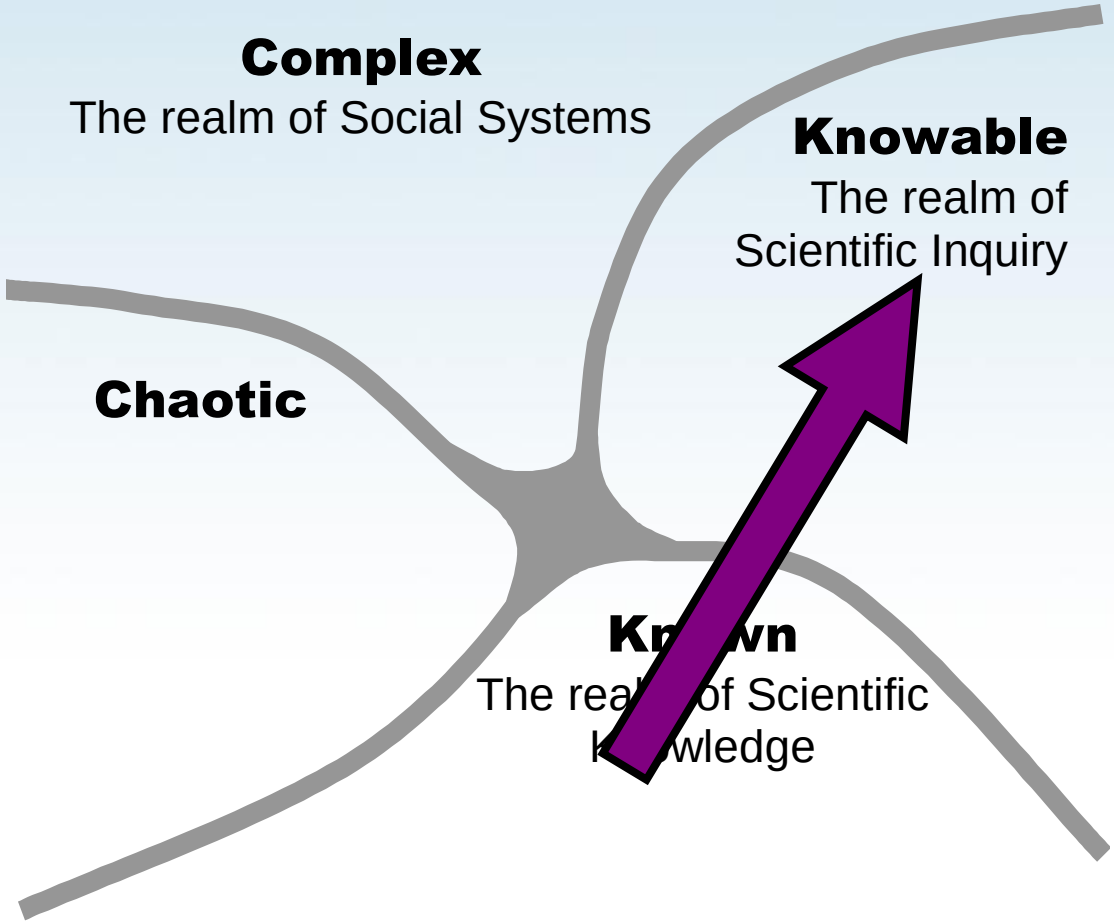
Cynefin: learning, repeatability



Repeatability and increasing familiarity

A conventional view of emergency management



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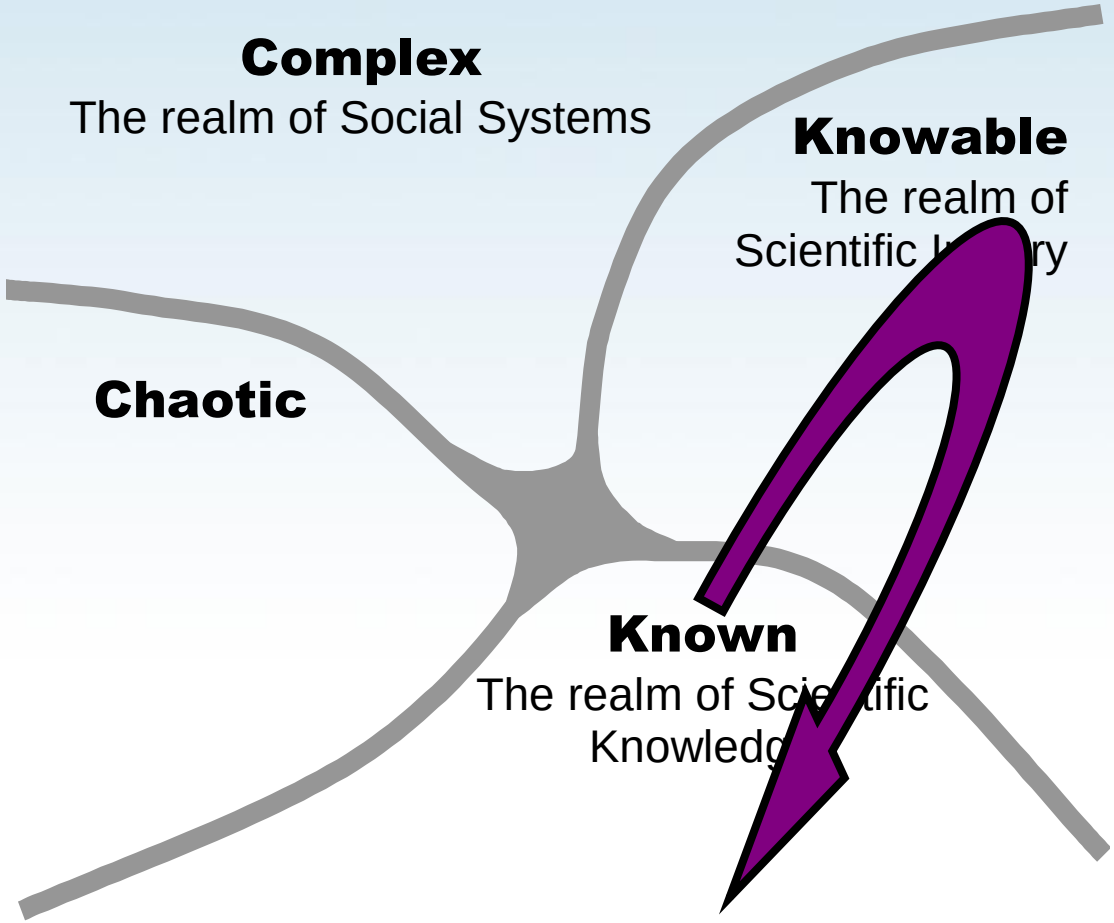
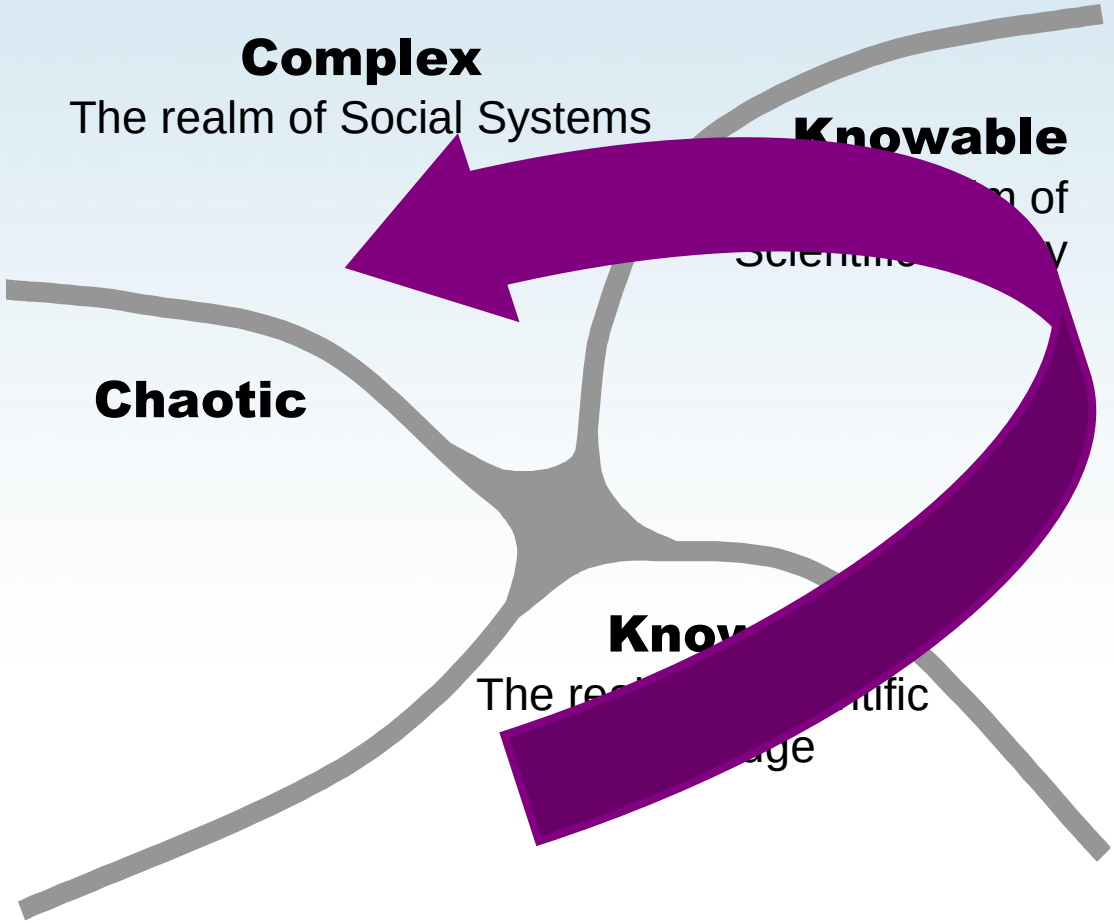
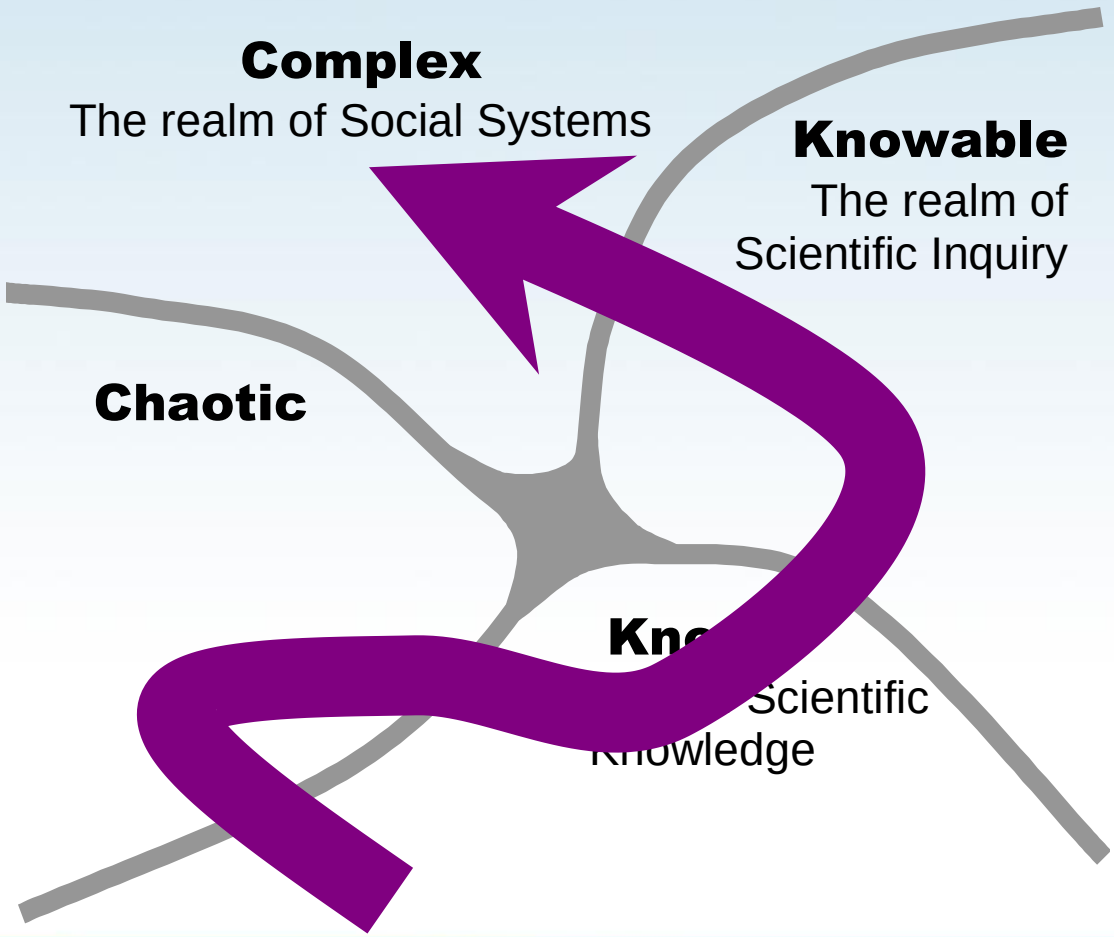


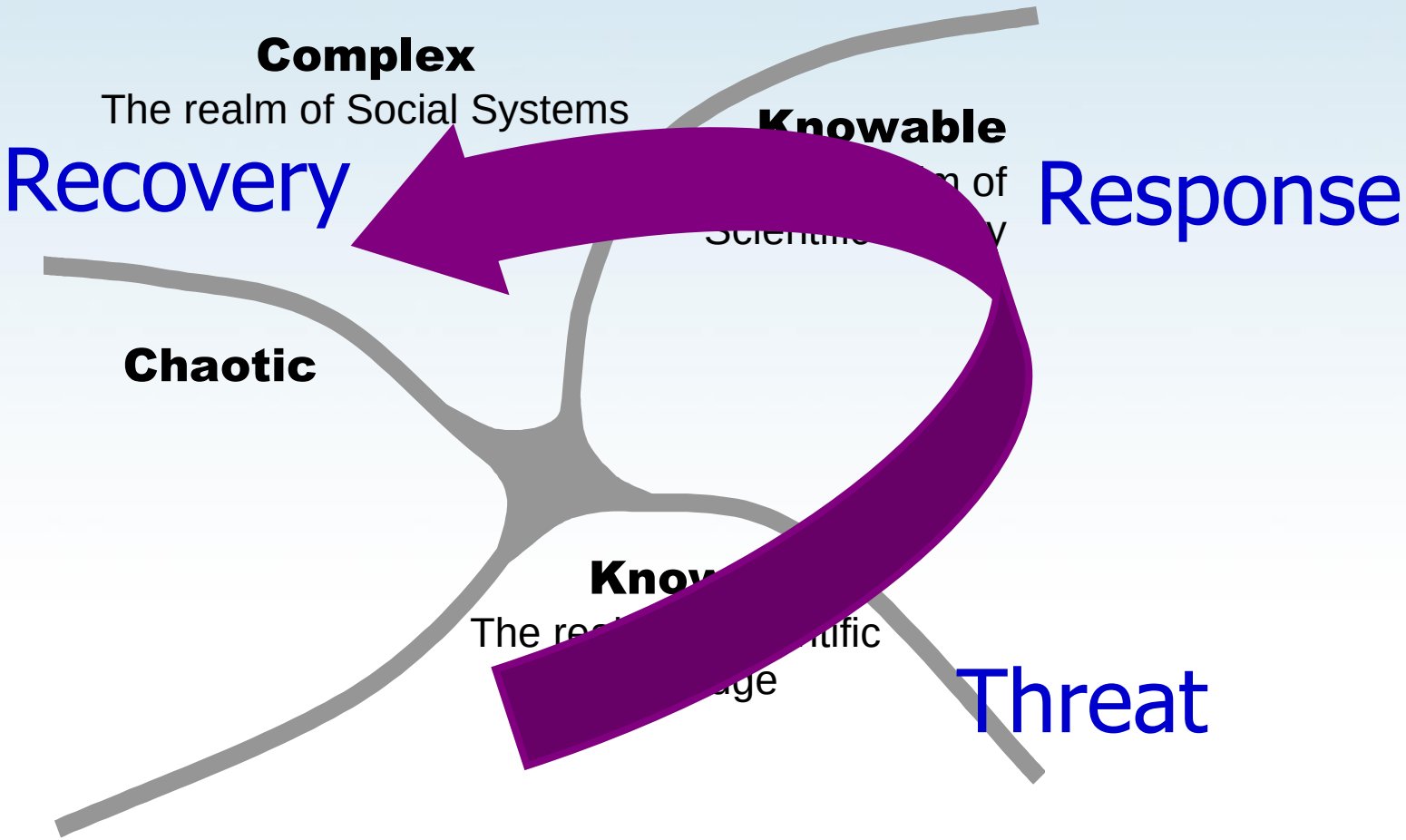
Chernobyl



Three Mile Island



More generally



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  - And decis
- System 1 v
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Communicating uncertainty is difficult

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  - **And decision makers!!!**
- System 1 vs System 2 thinking

System 1 and System 2 Thinking

- **System 1**
  - ‘intuition’ or ‘gut reaction’
  - superficial analysis/interpretation of the relevant information
  - based on much simpler forms of thinking on the fringes or outside of consciousness. ⇒ **FAST**
- **System 2**
  - conscious analytical thought
  - detailed evaluation of a broad range of information . ⇒ **SLOW**
  - often based on a rule that is assumed to provide the ‘correct’ answer or solution;
  - Note System 2 does not mean forgetting emotions and values.

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Density of information

- Chapman, Ehrenberg and others advised that 3 or 4 messages in a statistical table or figure were plenty. Any more confused more than enlightened
- What is the density of information in a map?

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Density of information

- Chapman, Ehrenberg and others advised that 3 or 4 messages in a statistical table or figure were plenty. Any more confused more than enlightened
- What is the density of information in a map?
- Remember that people believe maps are accurate. So showing uncertainty on a map is going to be hard.

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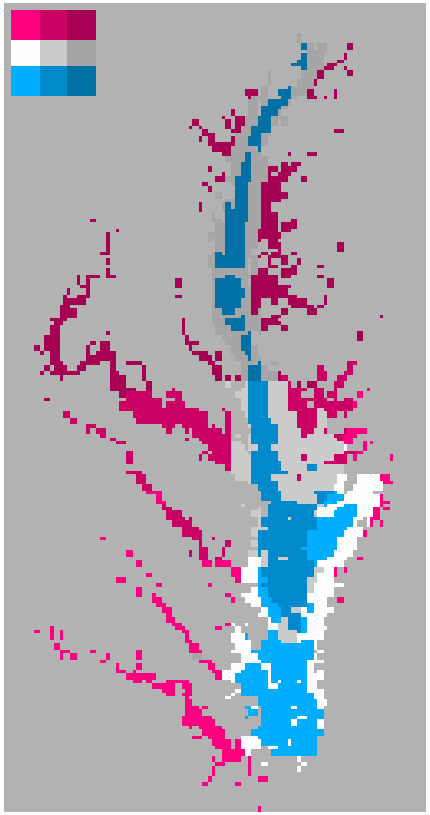
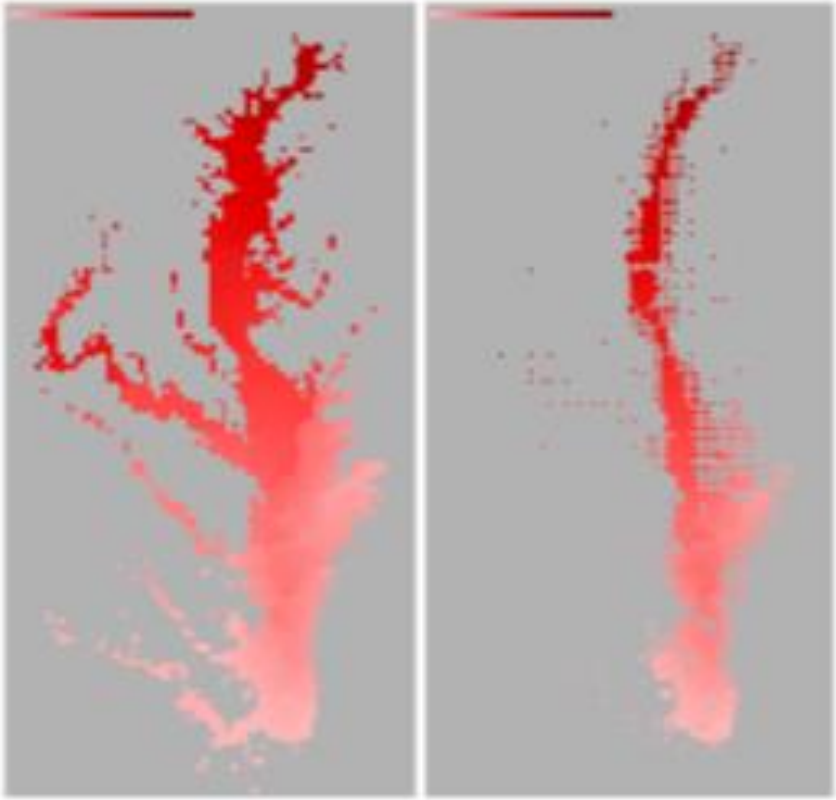
Alternative depictions of inorganic nitrogen in Chesapeake Bay and uncertainty of data interpolated from sparse point samples. (MacEachren et al, 2005)



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.



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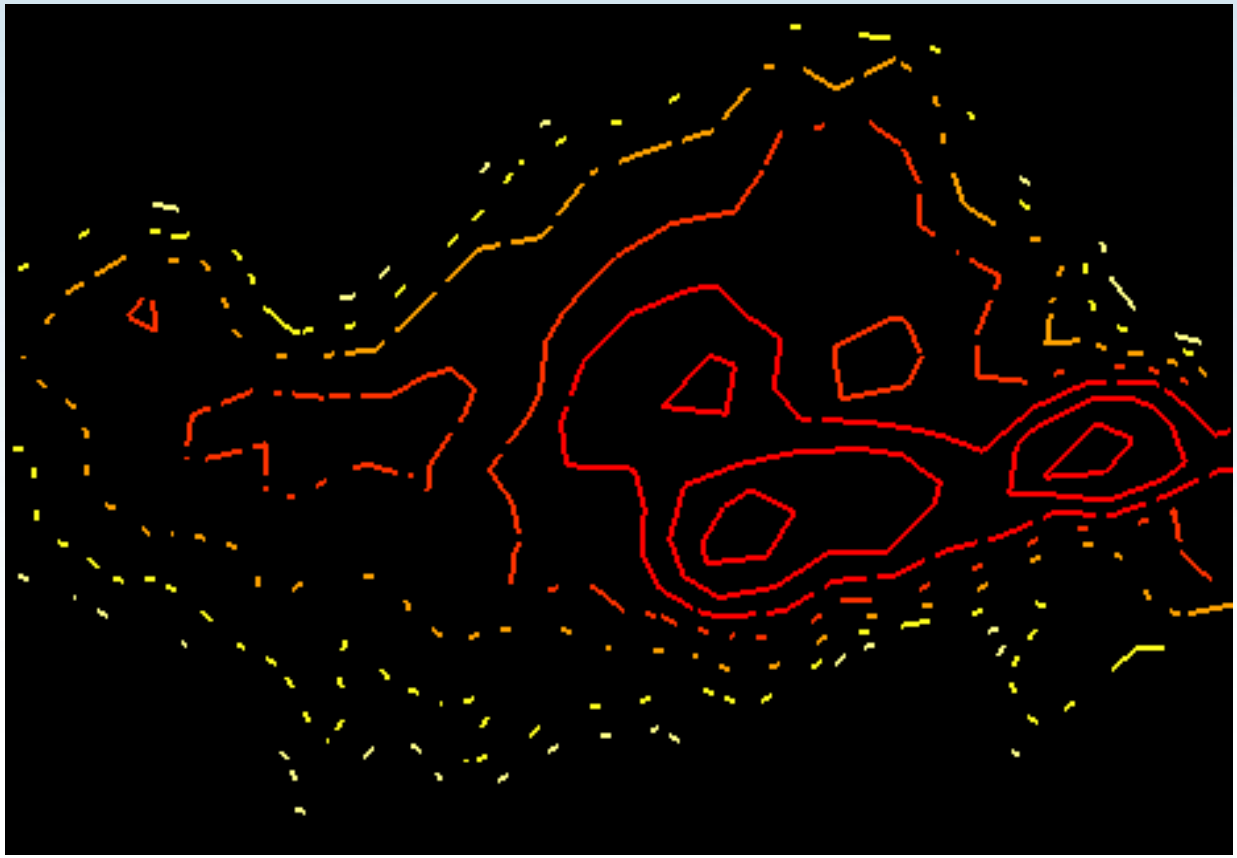
One possible convention



Spatial uncertainty in temperature, humidity, whatever is encoded as gaps in contour lines. The more uncertain, the larger the gaps. (Pang, 2011)

To use this convention it would probably be necessary to strip out many of the other details on the map (or just under the area concerned)