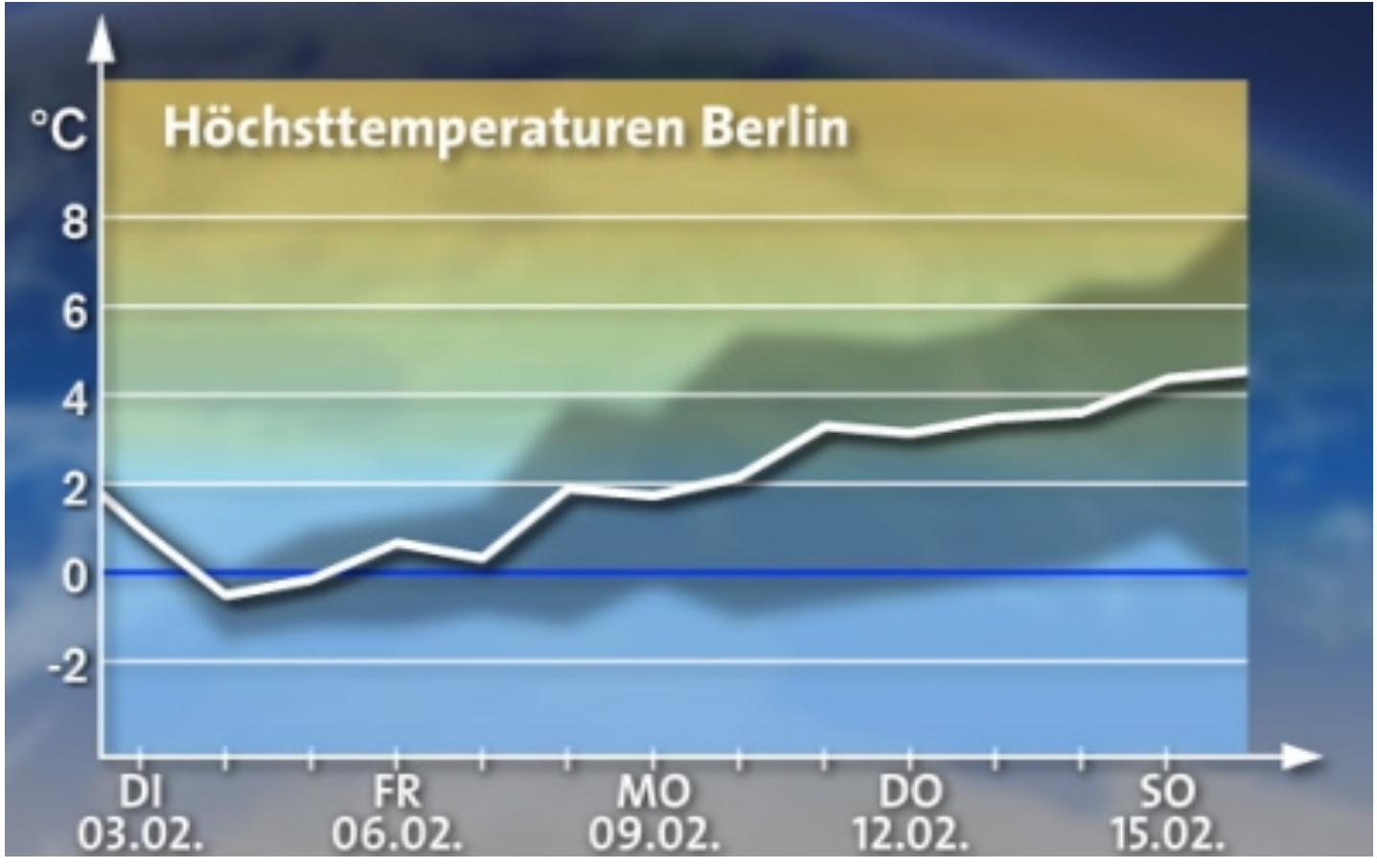
DATA ANALYSIS UNDER UNCERTAINTY

Christoph Kinkeldey

References: http://tiny.cc/va2017-ref

Inria

Temperature forecast



http://wetterbilder.daserste.de/

Motivation

Important to be informed about uncertainty when

- analyzing and understanding data
- making decisions based on data

http://visualization.ischool.uw.edu/hci_uncertainty/

Uncertain information is hard to interpret!
(even if uncertainty is successfully communicated)

Overview

I. Concept: What is uncertainty?

II. Visualization: How to visualize uncertainty?

III. Usage: Decisions under uncertainty

Part I / III: Concept of uncertainty

Uncertainty in a nutshell

»[T]here are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns – there are things we do not know we don't know.«

Donald Rumsfeld, former United States Secretary of Defense, February 12, 2002

Uncertainty // Sources

- Variability in nature
- Deficiency in measurement methods and equipment (resolution, accuracy…)
- Deficiency in modeling (imprecision, lack of complexity…)
- Insufficient of conflicting information
- Others, e.g. uncertainty introduced when visualizing

Geodata Uncertainty // Definition

Lack of knowledge about:

- objects of the real world due to
  - erroneous measurement,
  - vague definitions and concepts or
  - unknown and ambiguous meaning
- effects of transformations performed on the data
- the data's suitability for the intended application

(Leyk 2005)

Uncertainty // Definition

Uncertainty and *error* are different concepts!

Error: True value is known
Uncertainty: True value is not known

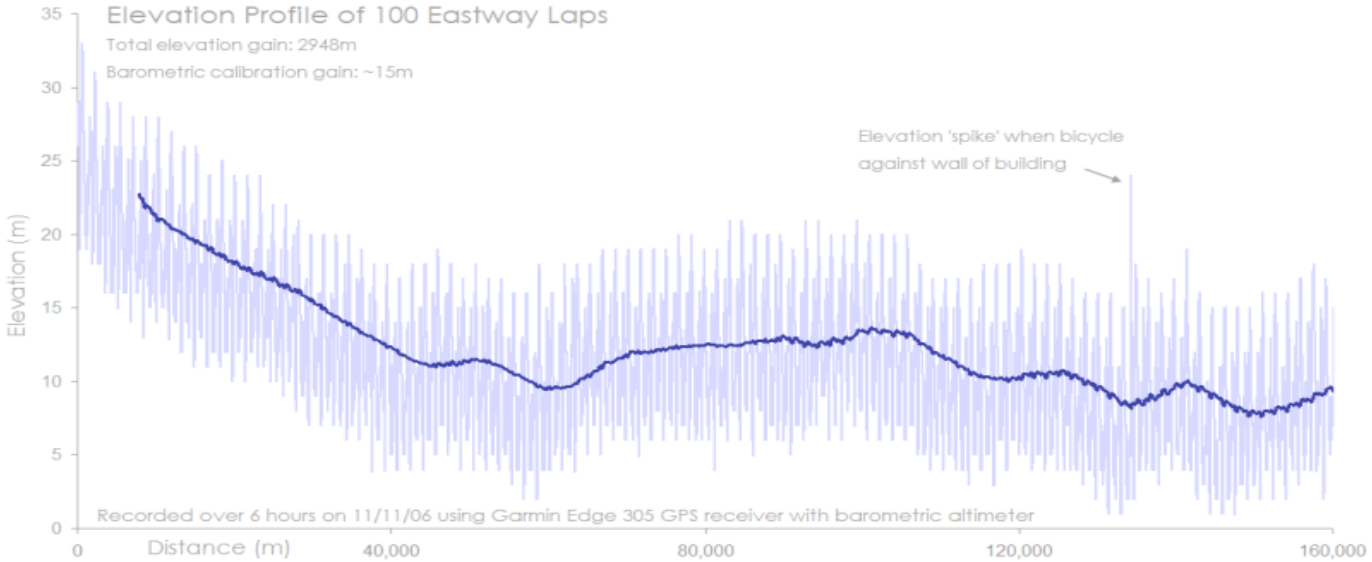
Uncertainty always describes a *lack of knowledge*

Uncertainty // Definition

Measurement of height with GPS:

Error: 10m (if we know the exact value)

Uncertainty: +/- 10m (may be known from the GPS device)



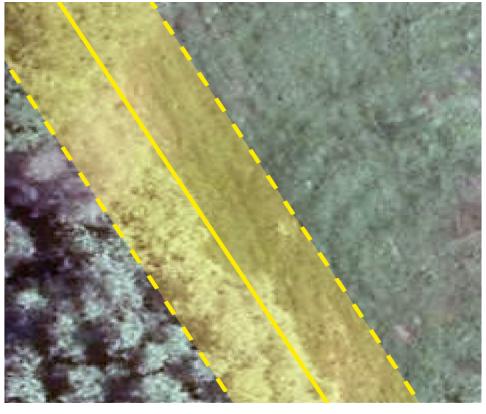
http://www.staff.city.ac.uk/~jwo/landserf/audax/elevation

Geodata Uncertainty // Categories

Attribute uncertainty

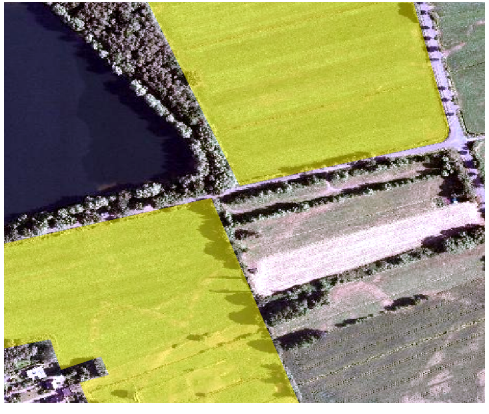
Decidious forest?
Mixed forest?

Geometric uncertainty

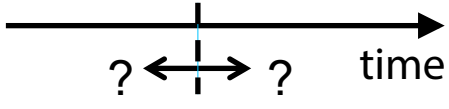


Position of boundary?

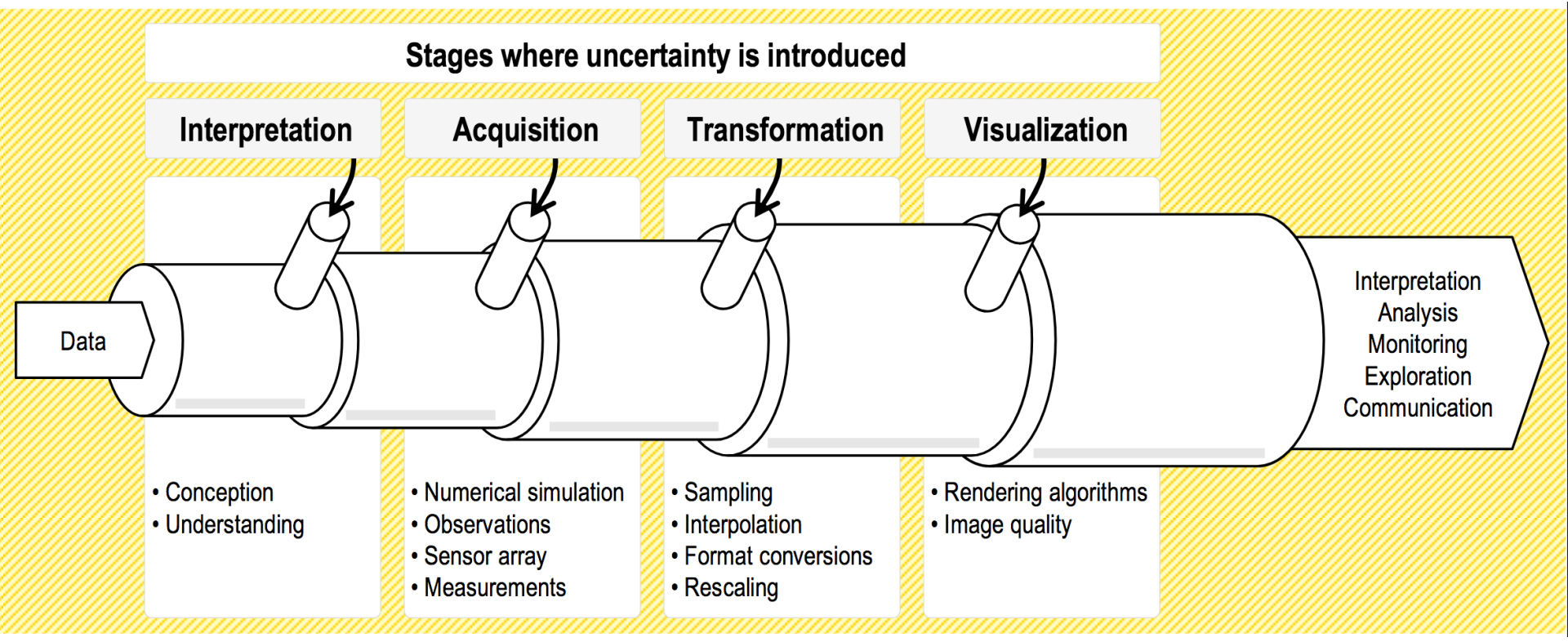
Temporal uncertainty



Valid for what time interval?

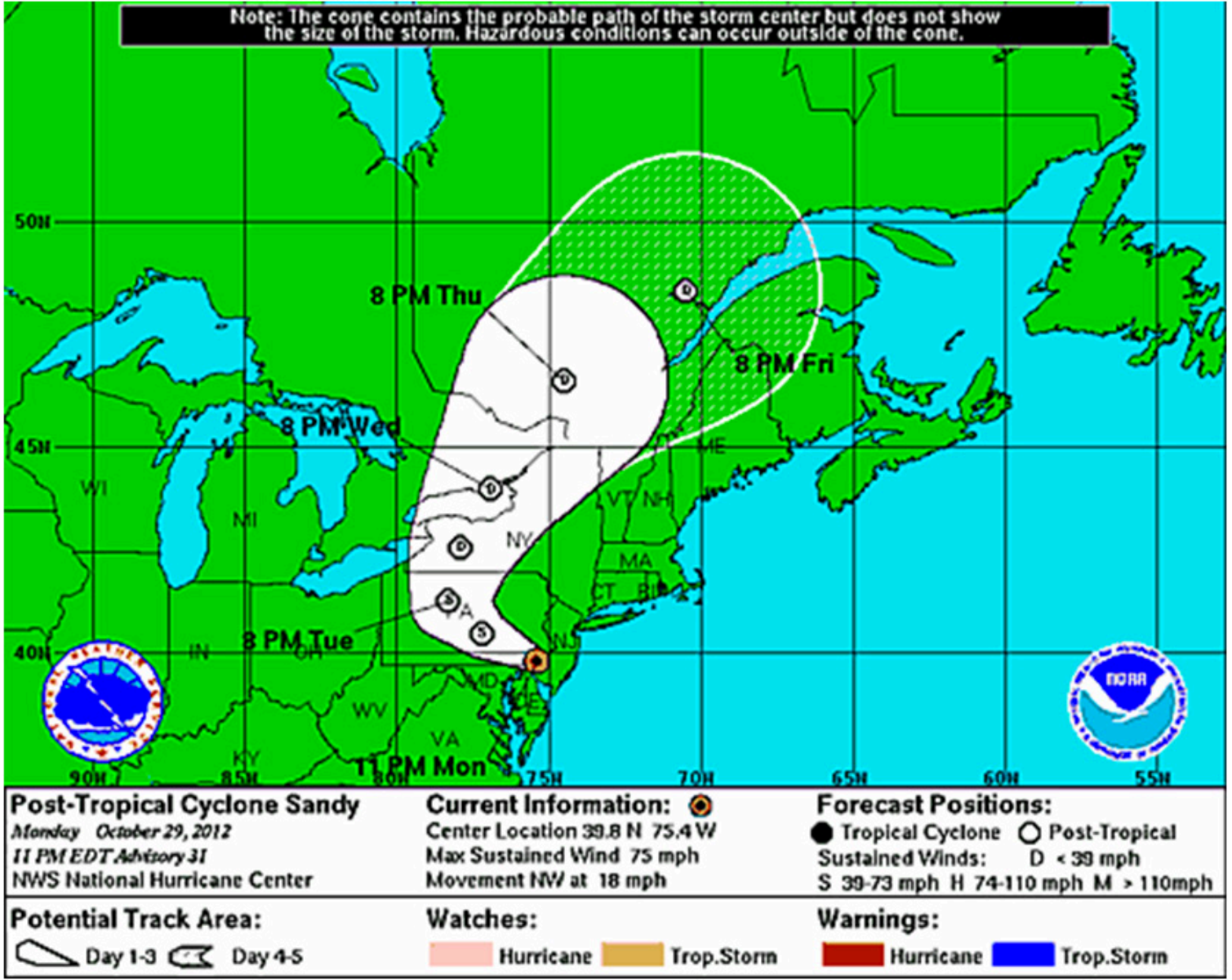


Uncertainty Visualization Pipeline

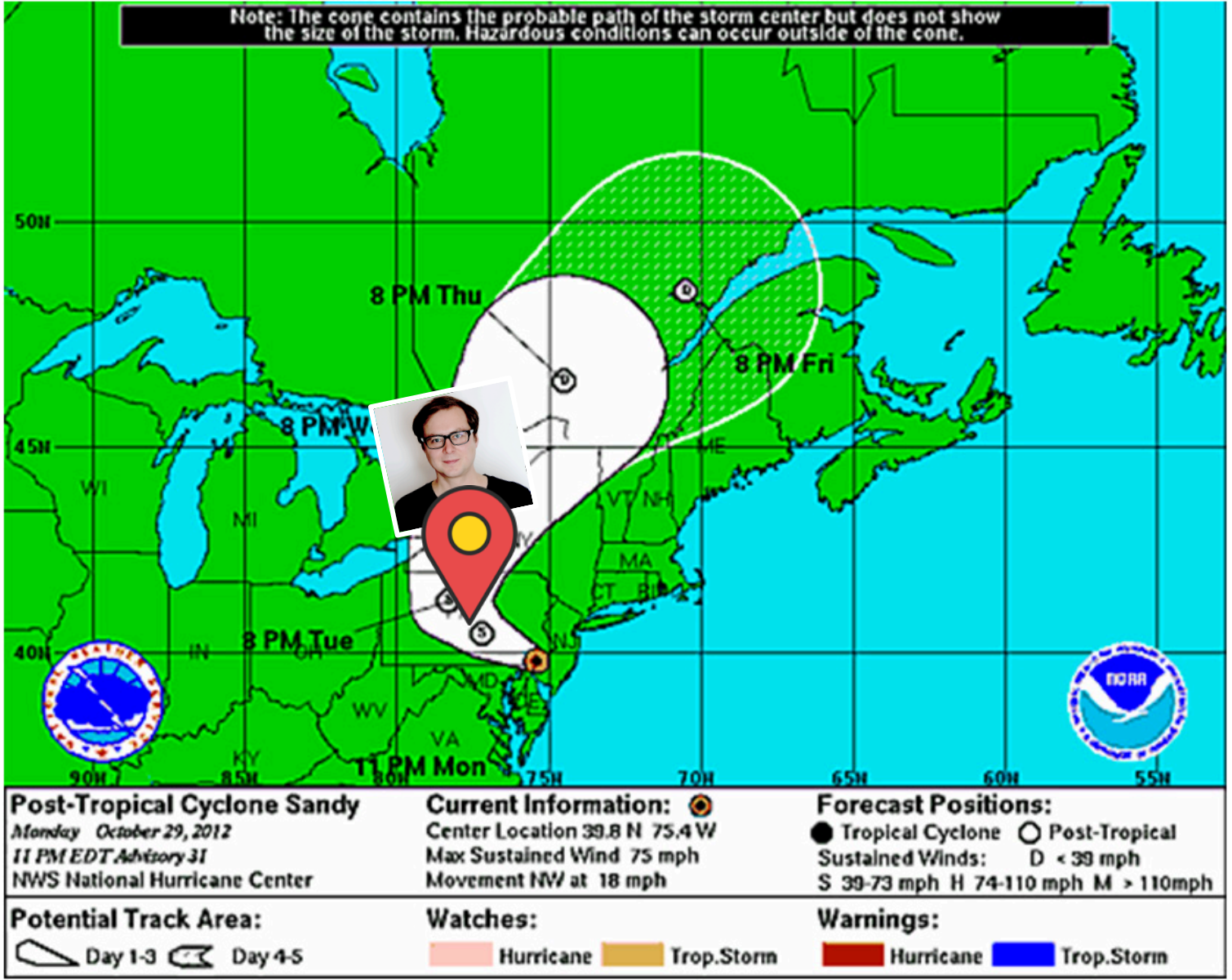


(Alberti 2013)

Part I / III: Uncertainty visualization


Note: The cone contains the probable path of the storm center but does not show the size of the storm. Hazardous conditions can occur outside of the cone.
50N
45N
40N
90W
85W
80W
75W
70W
65W
60W
55W
8 PM Thu
8 PM Fri
8 PM Wed
8 PM Tue
11 PM Mon
WI
MI
NY
PA
NJ
MD
DE
WV
VA
KY
IN
OH
VT
NH
ME
MA
CT
RI
Post-Tropical Cyclone Sandy
Monday October 29, 2012
11 PM EDT Advisory 31
NWS National Hurricane Center
Current Information:
Center Location 39.8 N 75.4 W
Max Sustained Wind 75 mph
Movement NW at 18 mph
Forecast Positions:
Tropical Cyclone
Post-Tropical
Sustained Winds: D < 39 mph
S 39-73 mph H 74-110 mph M > 110mph
Potential Track Area:
Day 1-3
Day 4-5
Watches:
Hurricane
Trop.Storm
Warnings:
Hurricane
Trop.Storm

NWS 2016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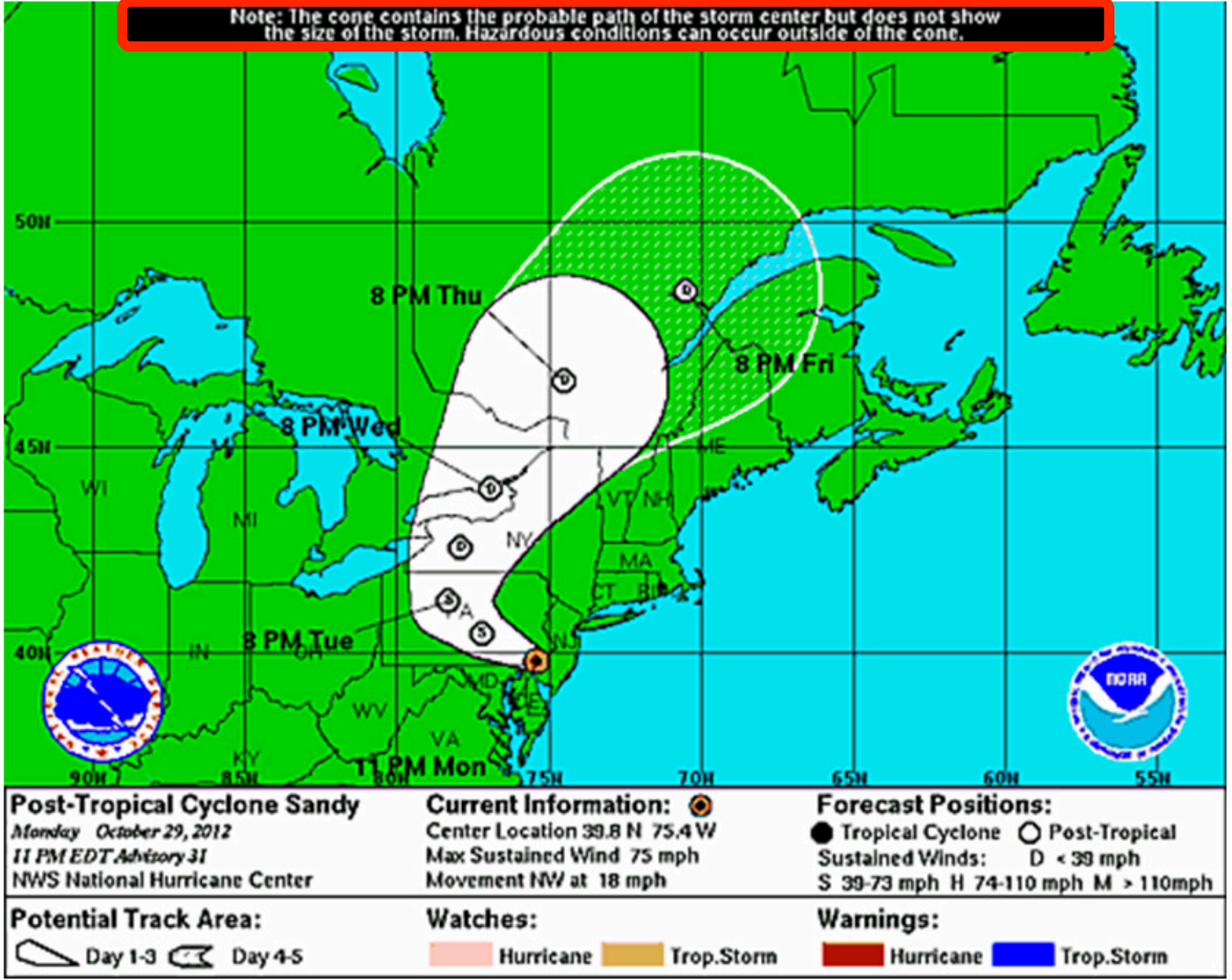
NWS 2016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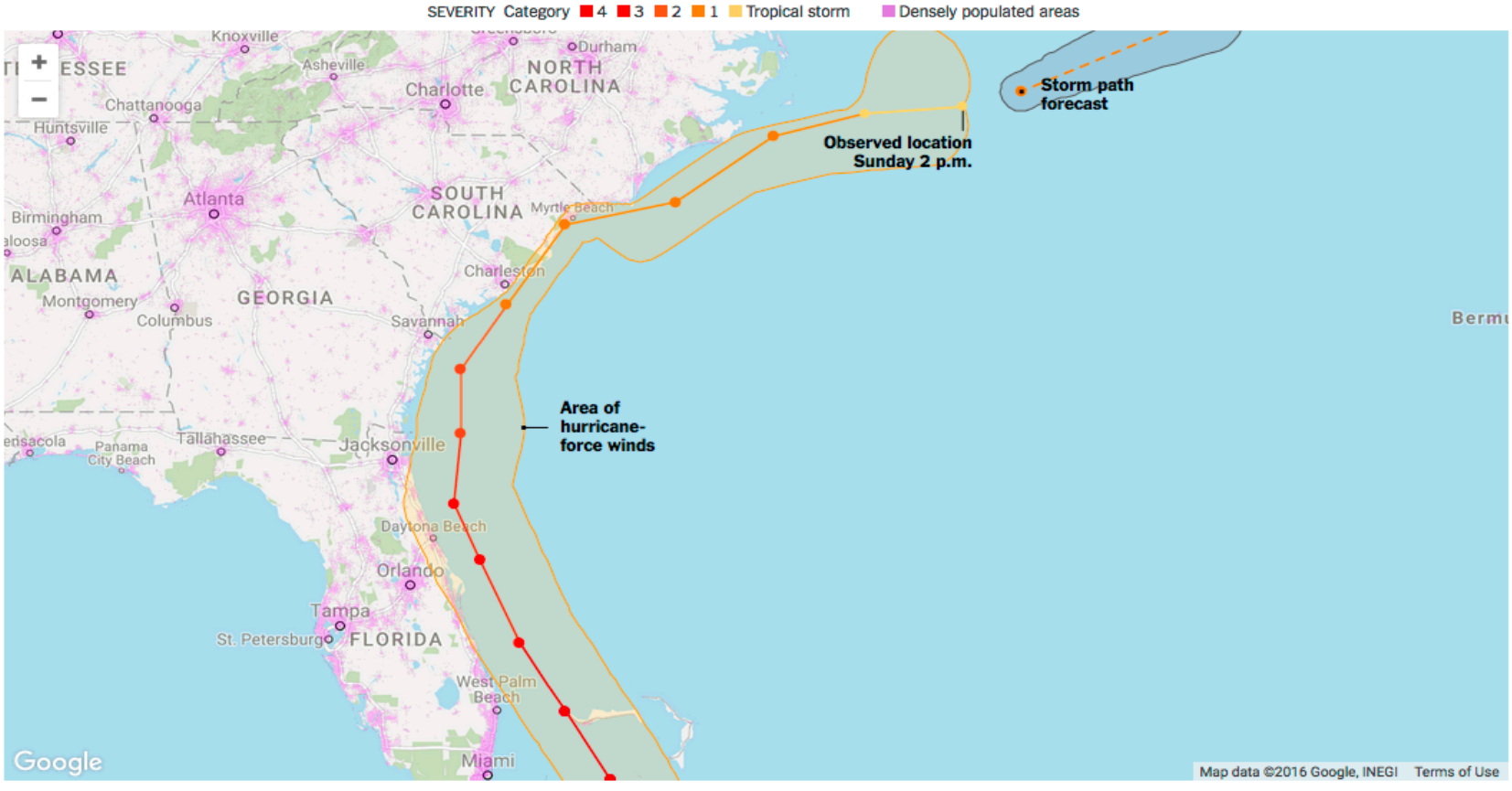
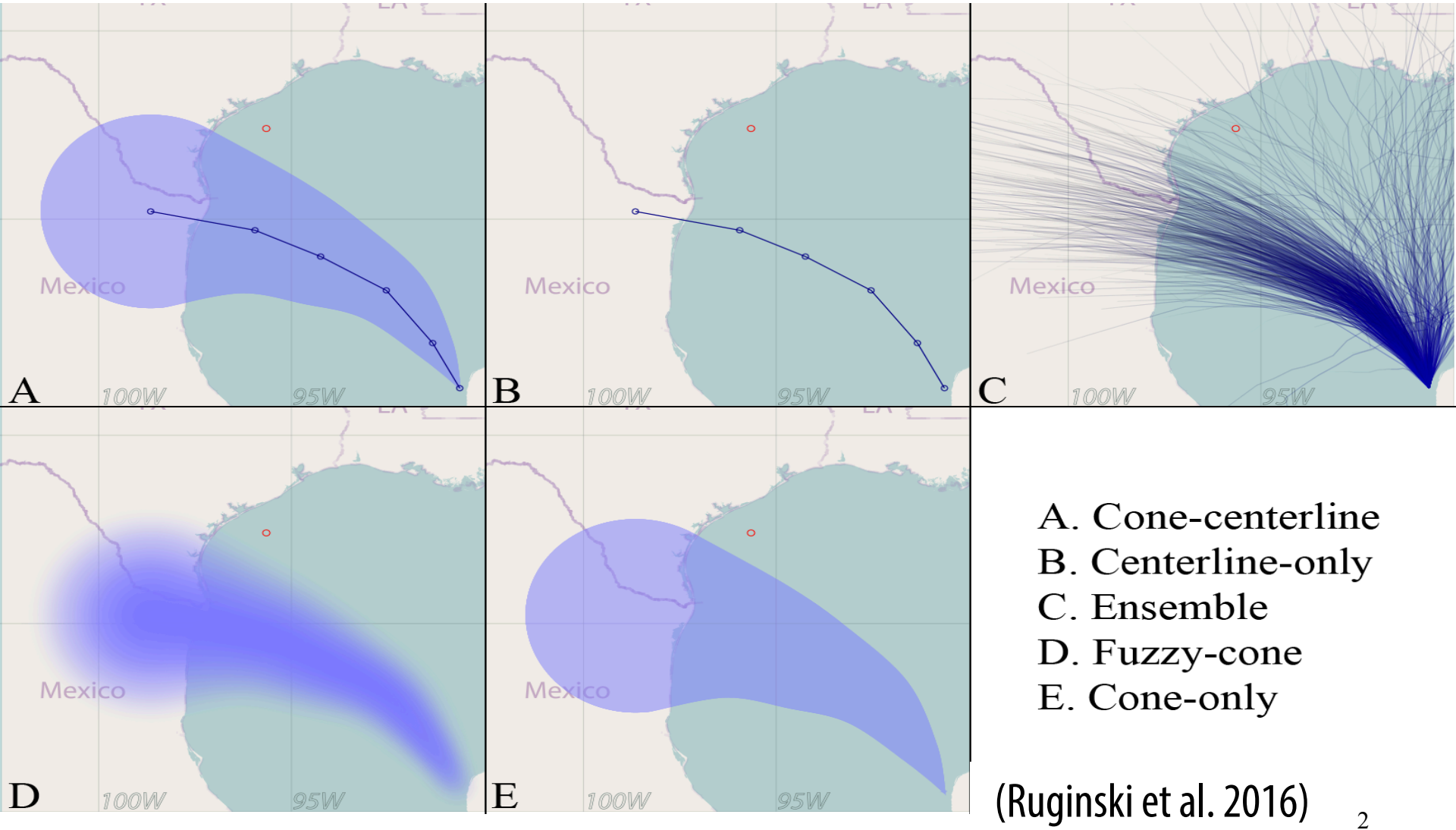
NWS 2016



Sources: National Weather Service; LandScan population database

(NYTimes 2016)



A. Cone-centerline
B. Centerline-only
C. Ensemble
D. Fuzzy-cone
E. Cone-only

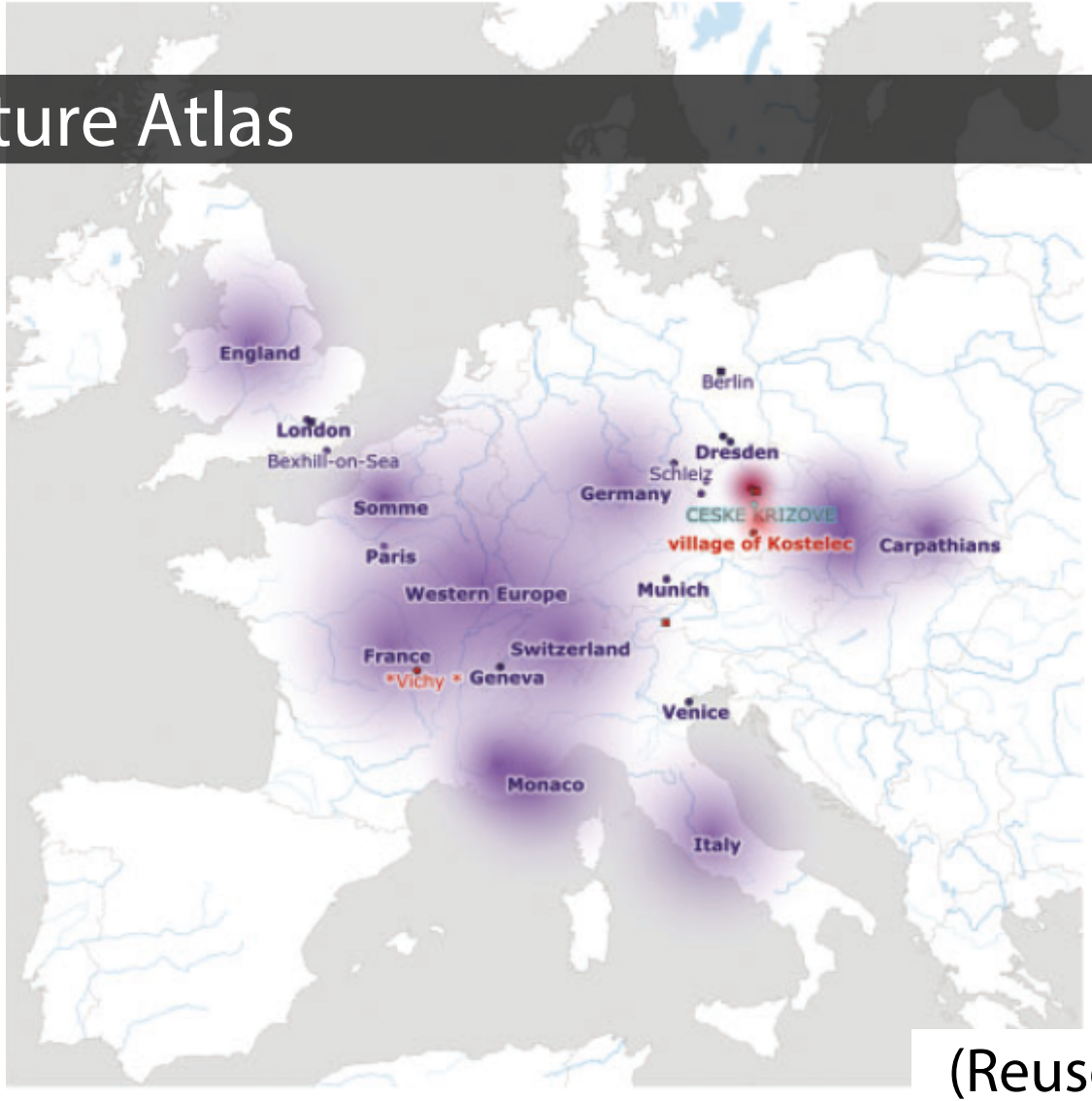
(Ruginski et al. 2016)

It‘s challenging to visualize uncertainty!

It is *meta-information* about other variables

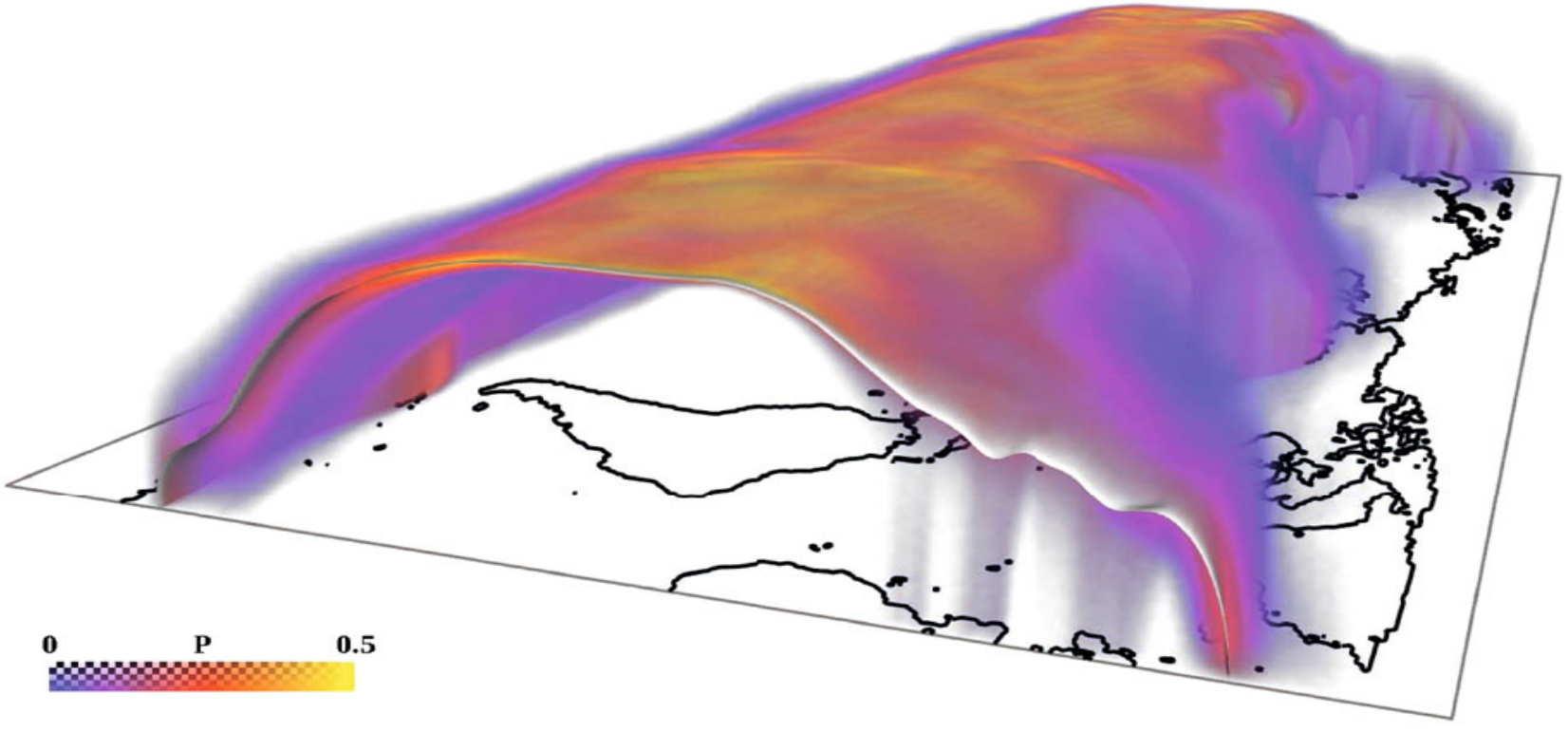
Intuitiveness of visualization is important

Literature Atlas



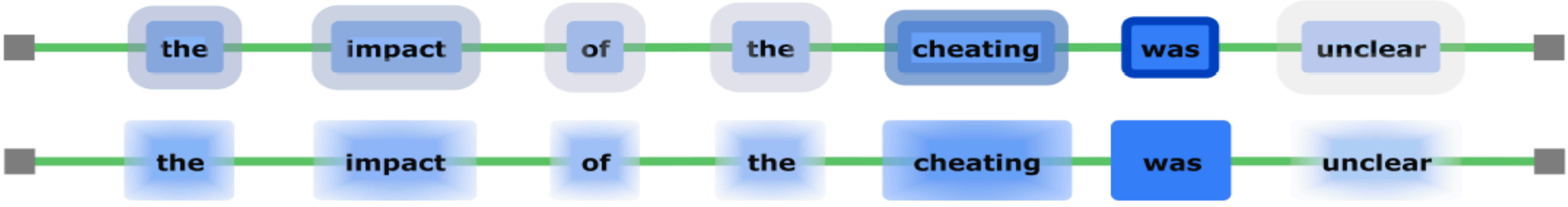
(Reuschel / Hurni 2011)

Global warming



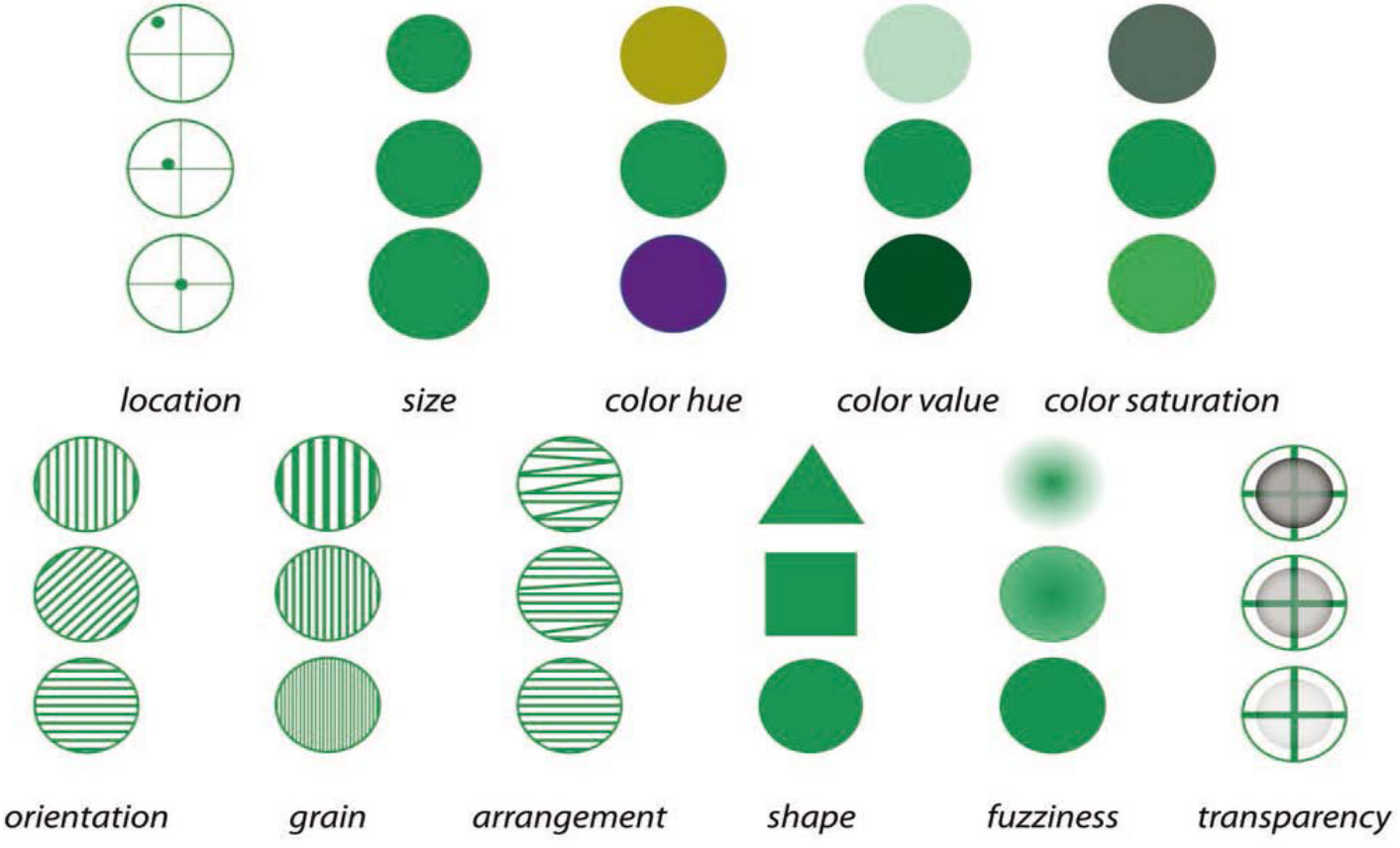
(Pöthkow et al. 2011)

Text recognition



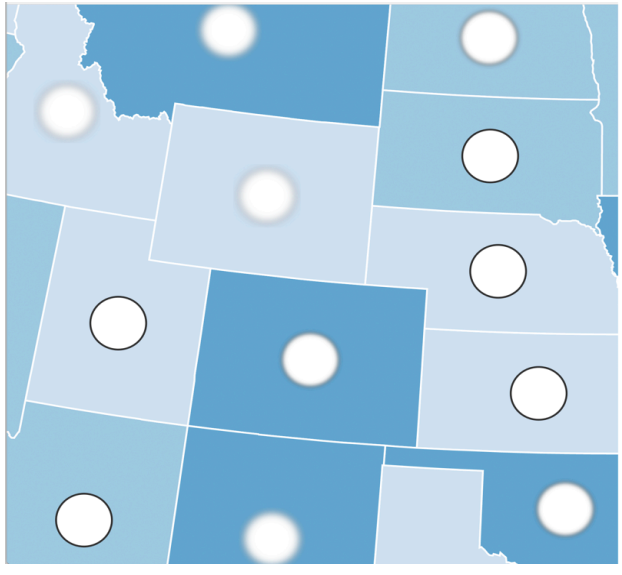
(Collins et al. 2007)

Visual Variables

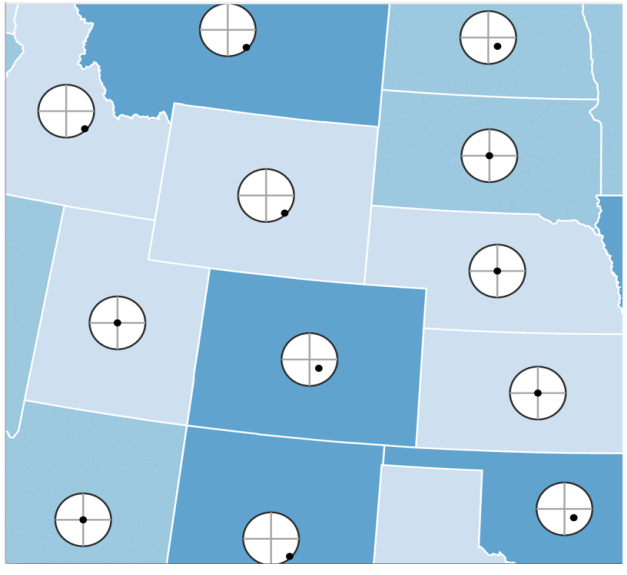


(MacEachren et al. 2012)

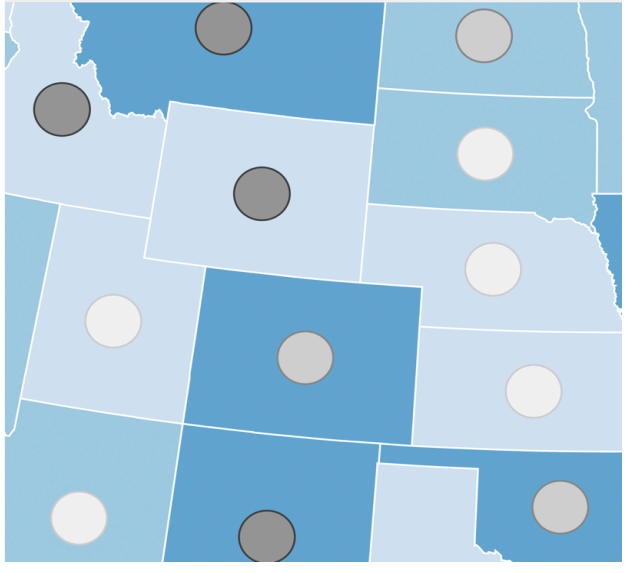
Visual Variables



Blur



Position

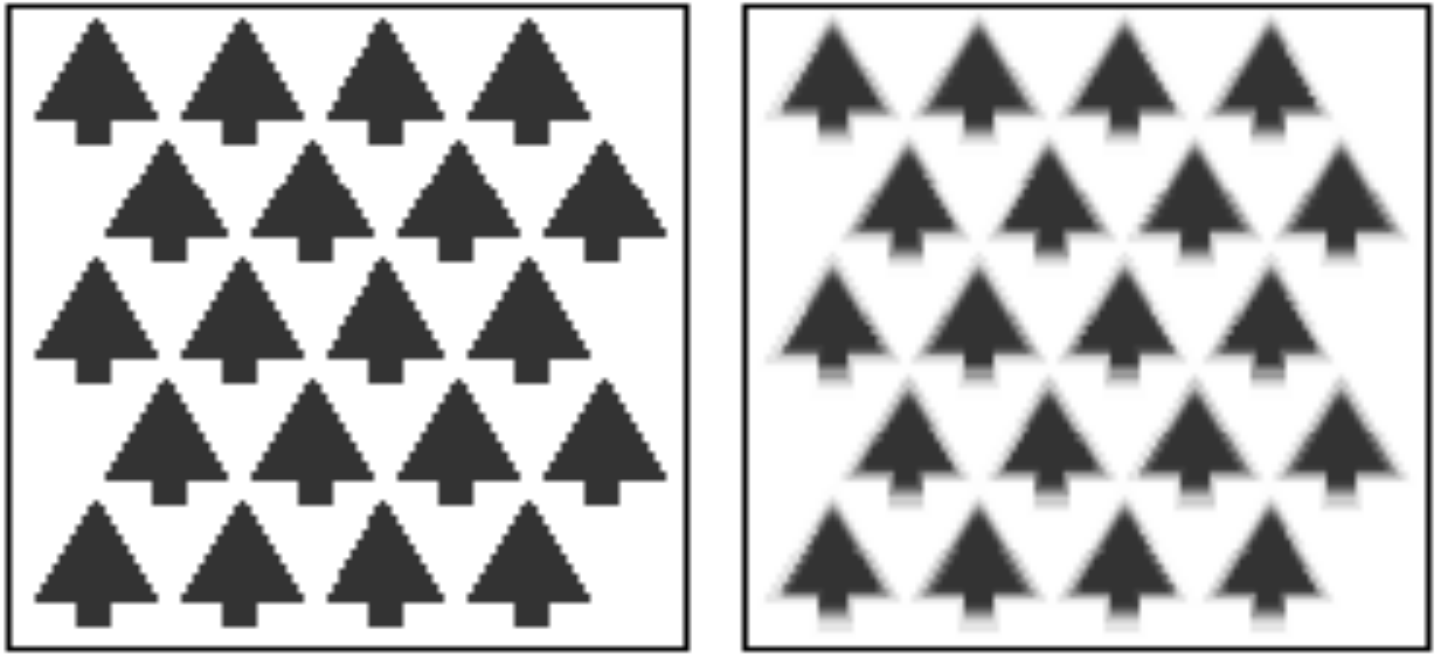


Color value

Visual metaphors

Visual metaphors (fog, clarity…) are deemed to increase intuitiveness of uncertainty displays

Visual metaphor “Clarity“

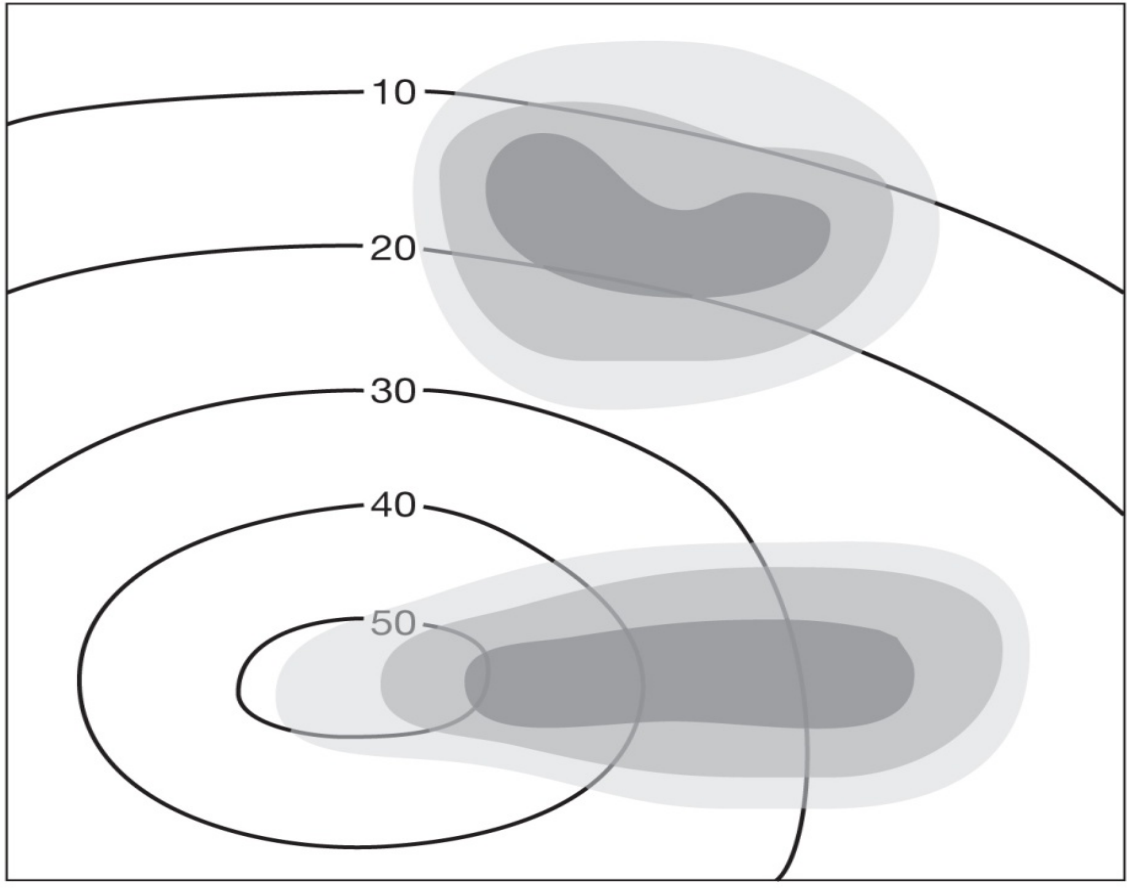


(MacEachren 1992)

Visual Metaphor: Fuzziness

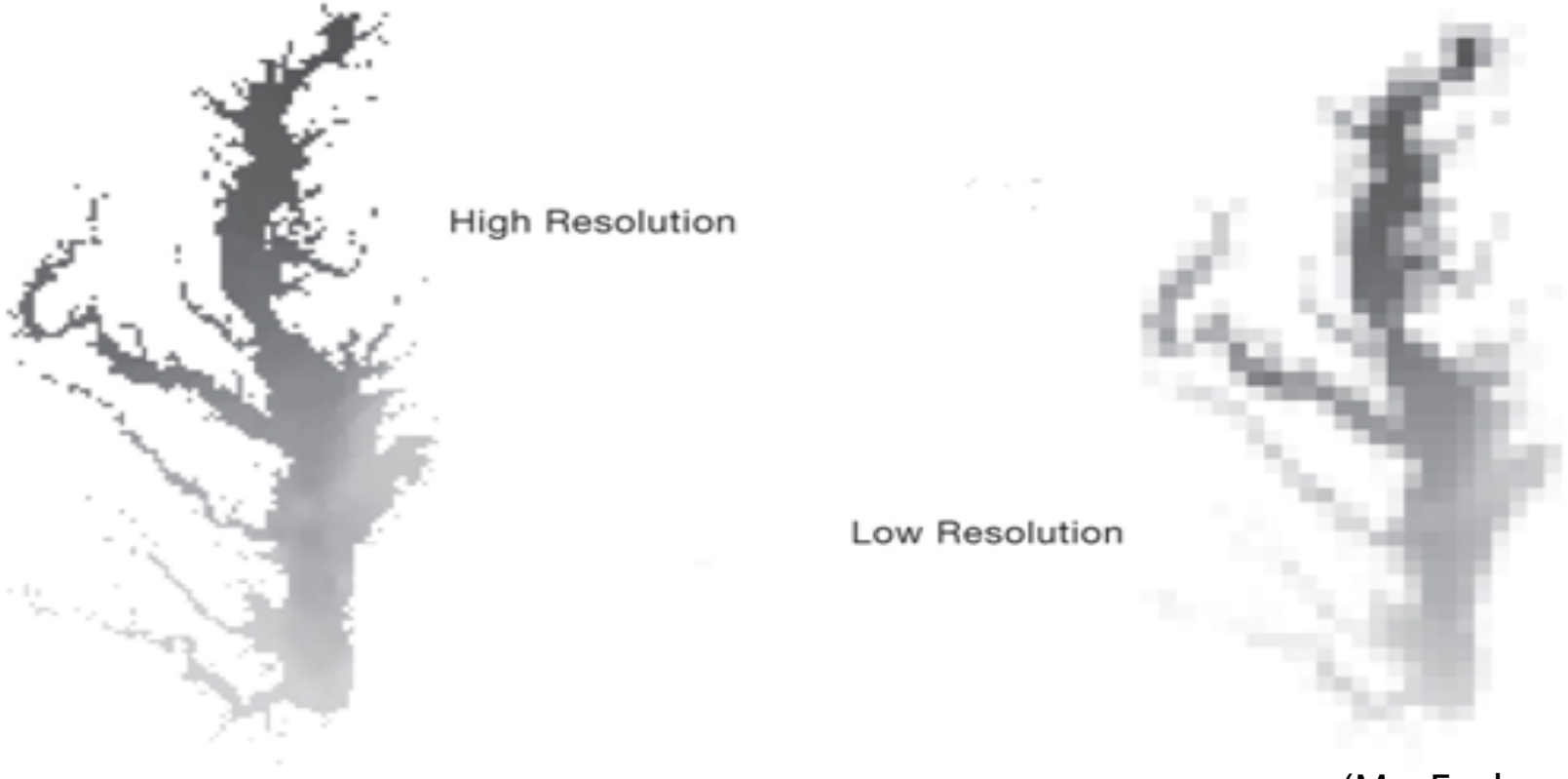
(MacEachren 1992)

Visual metaohor: Transparency (“fog“)



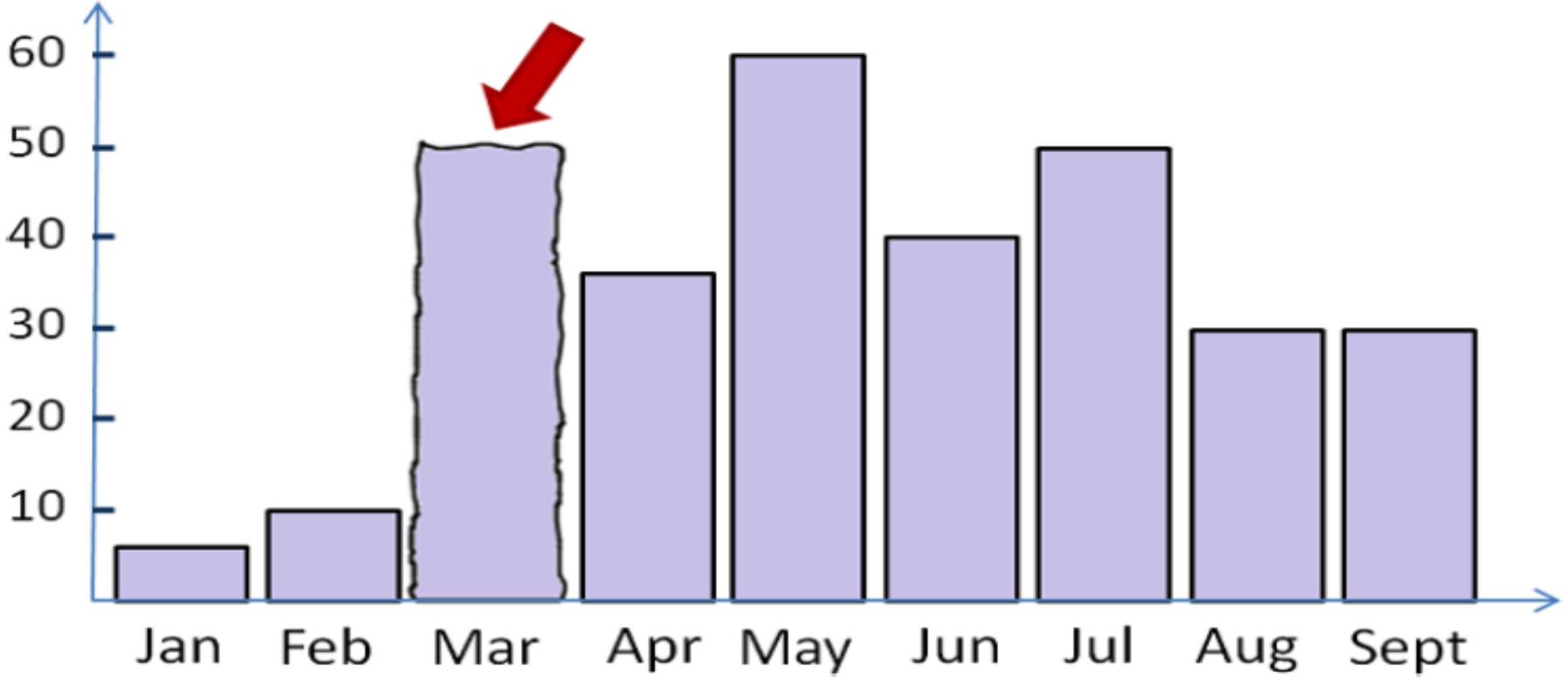
(MacEachren 1992)

Visual metaphor: Resolution



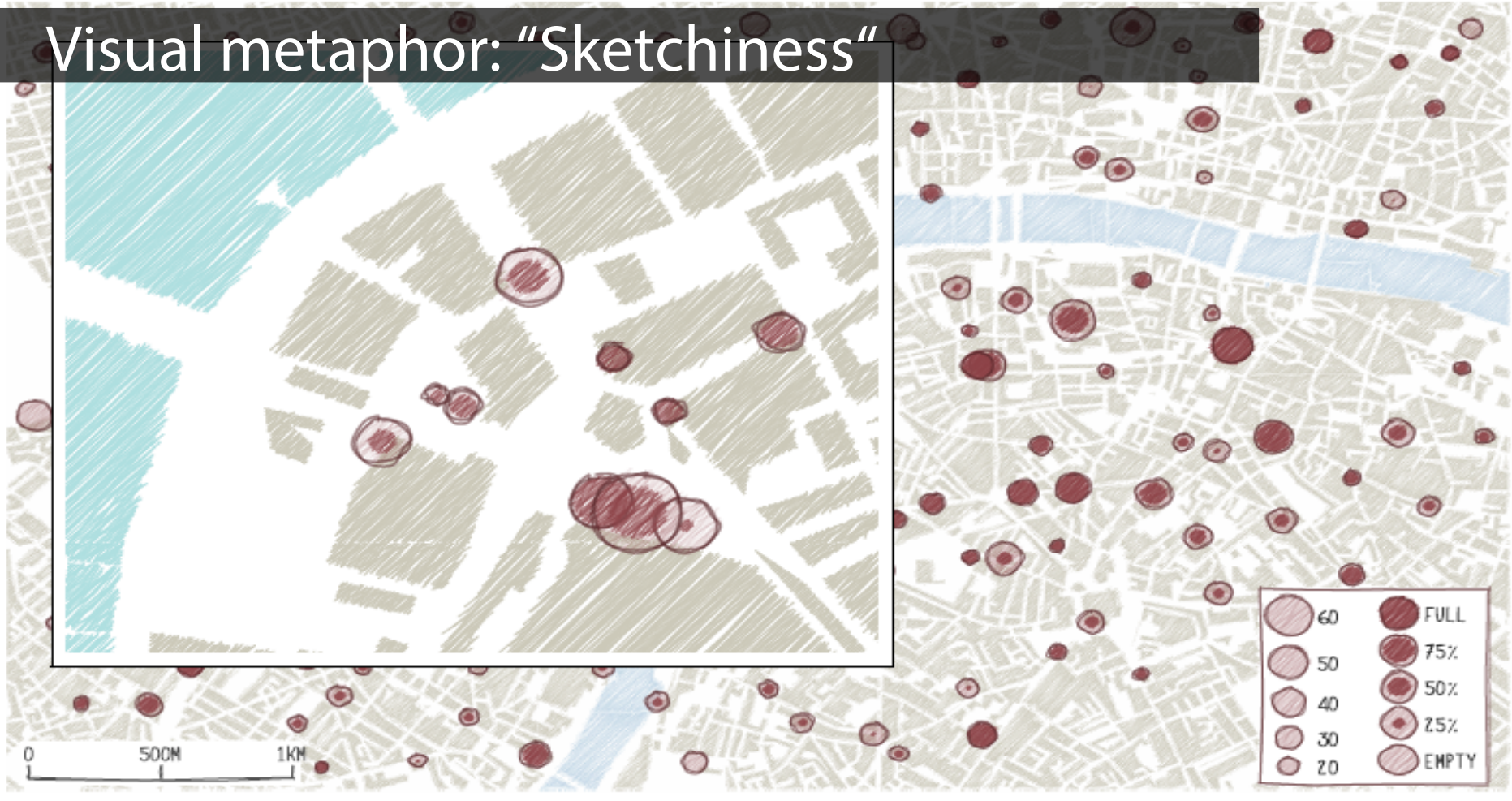
(MacEachren 1992)

Visual metaphor: “Sketchiness“



(Boukhelifa et al. 2012)

Visual metaphor: “Sketchiness“



(Wood et al. 2012)

Uncertainty Visualization

What are the best ways to depict uncertainty visually for analytical tasks?

Related to...

...accuracy,

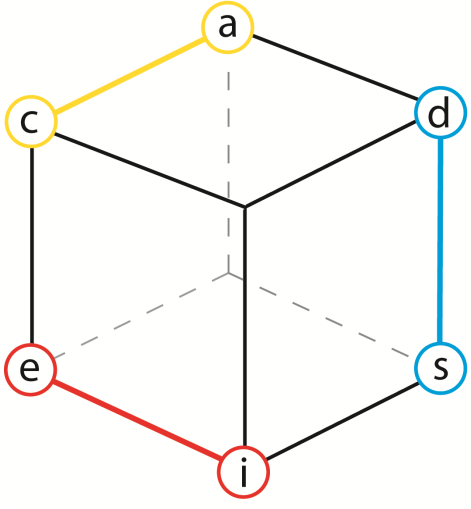
...speed,

...intuitiveness,

...user confidence, and

...preference

Uncertainty Vis Cube (UVis^3)



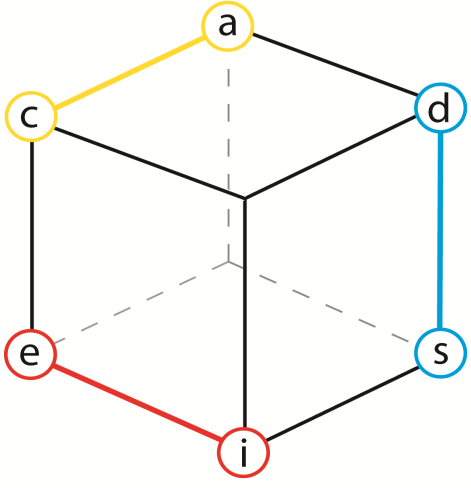
intrinsic / extrinsic

coincident / adjacent

static / dynamic

(Kinkeldey et al. 2014)

Uncertainty Vis Cube (UVis^3)

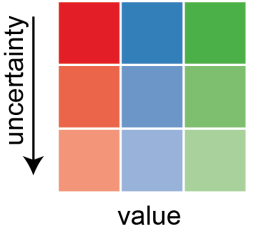


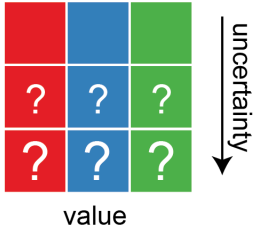
intrinsic / extrinsic

coincident / adjacent

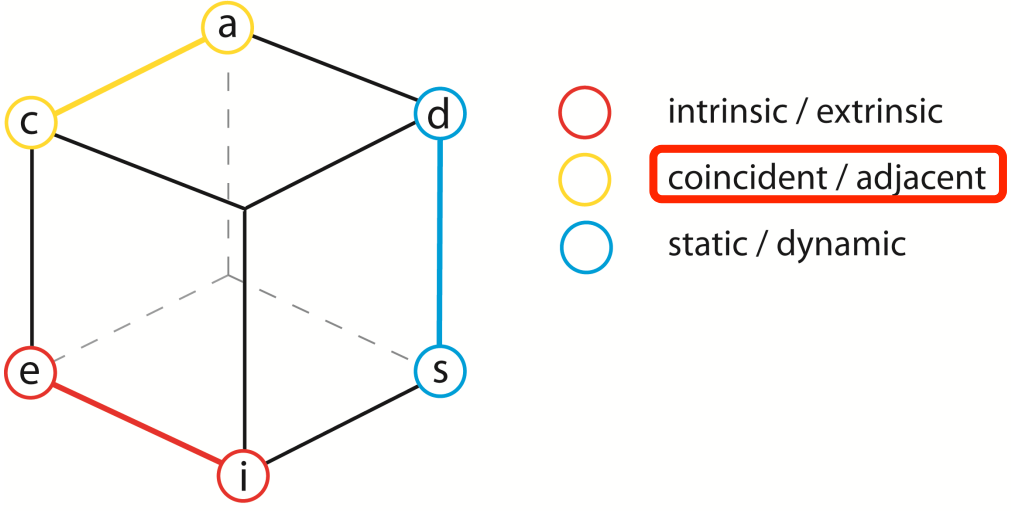
static / dynamic

- Intrinsic: Existing objects in the display are manipulated
- Extrinsic: Uncertainty is represented by additional objects in the display, e.g. symbols or grids





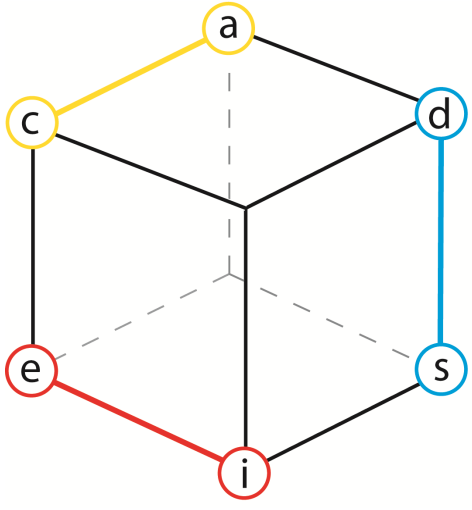
Uncertainty Vis Cube (UVis^3)



- Coincident: data & uncertainty in one view
- Adjacent: data & uncertainty in separate views

(Kinkeldey et al. 2014)

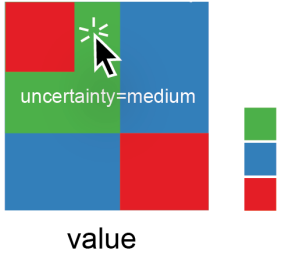
Uncertainty Vis Cube (UVis^3)



intrinsic / extrinsic

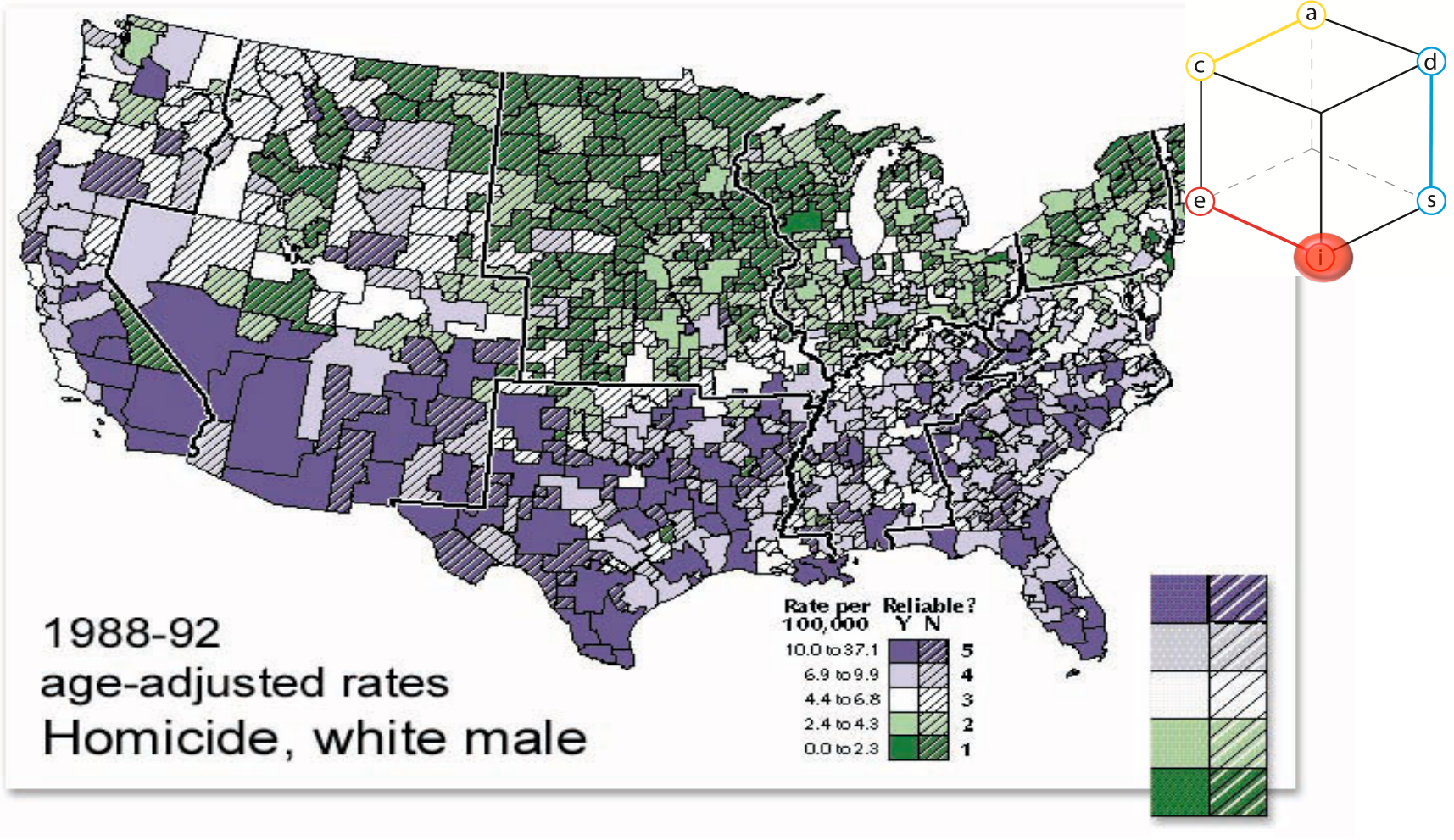
coincident / adjacent

static / dynamic

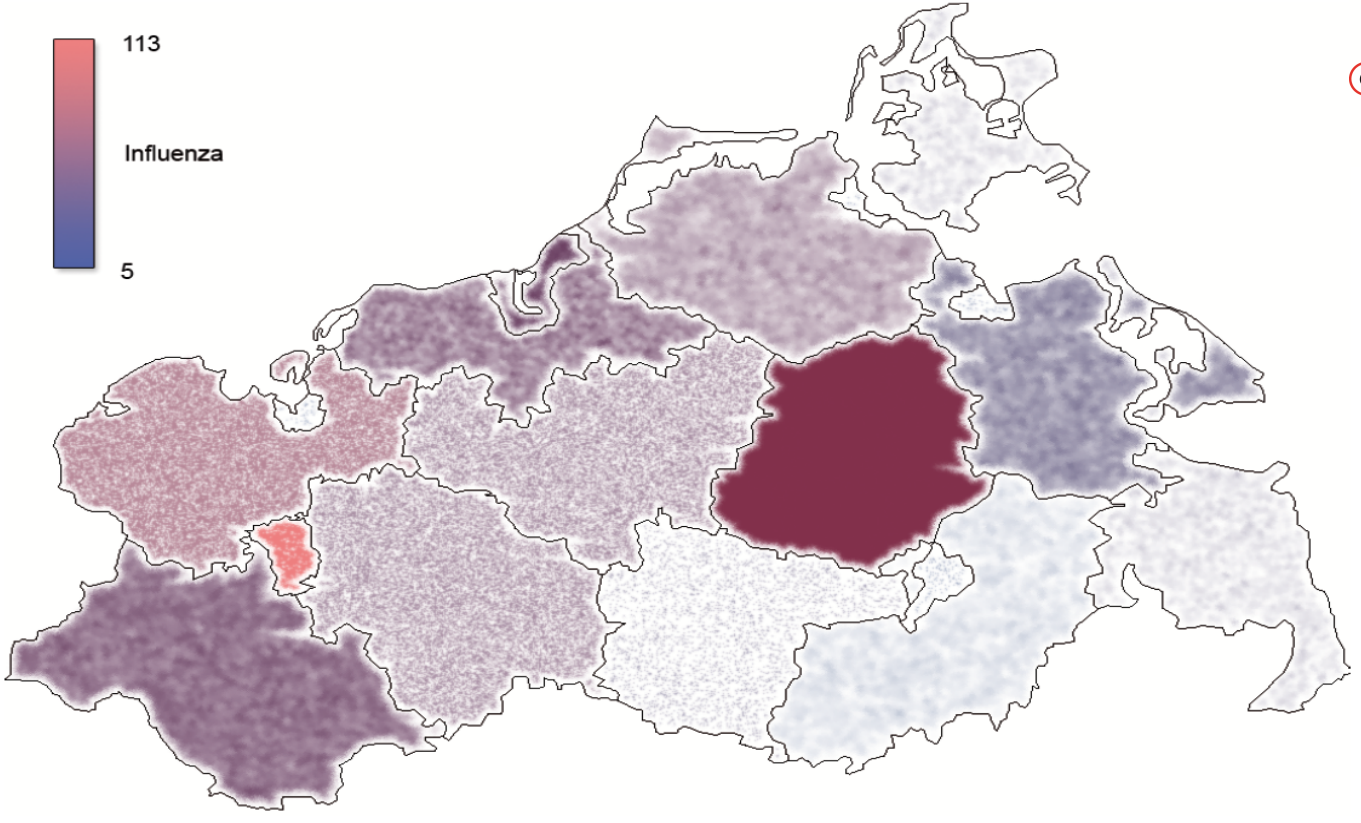


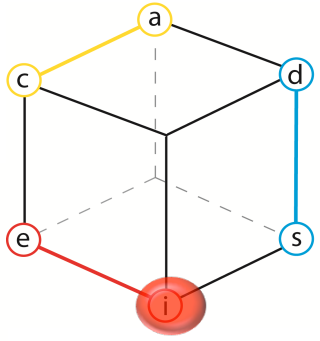
- Static: uncertainty visualization is static
- Dynamic: uncertainty visualization uses animation and/or interaction

(Kinkeldey et al. 2014)

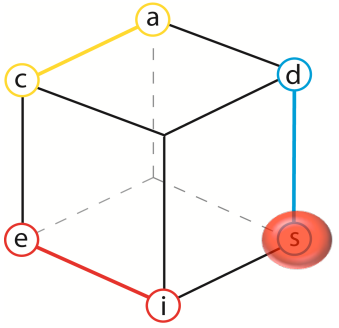


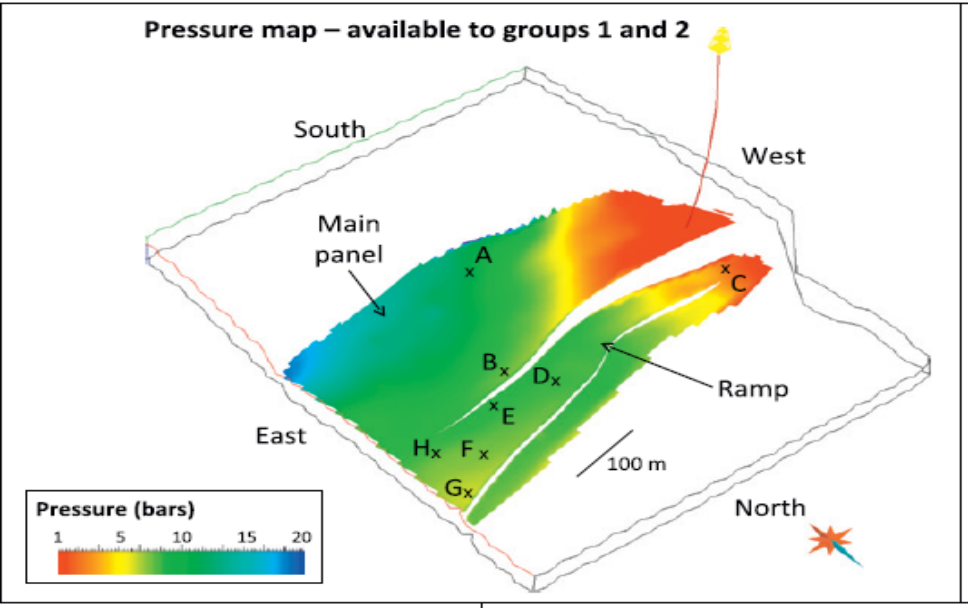
(MacEachren et al. 1998)

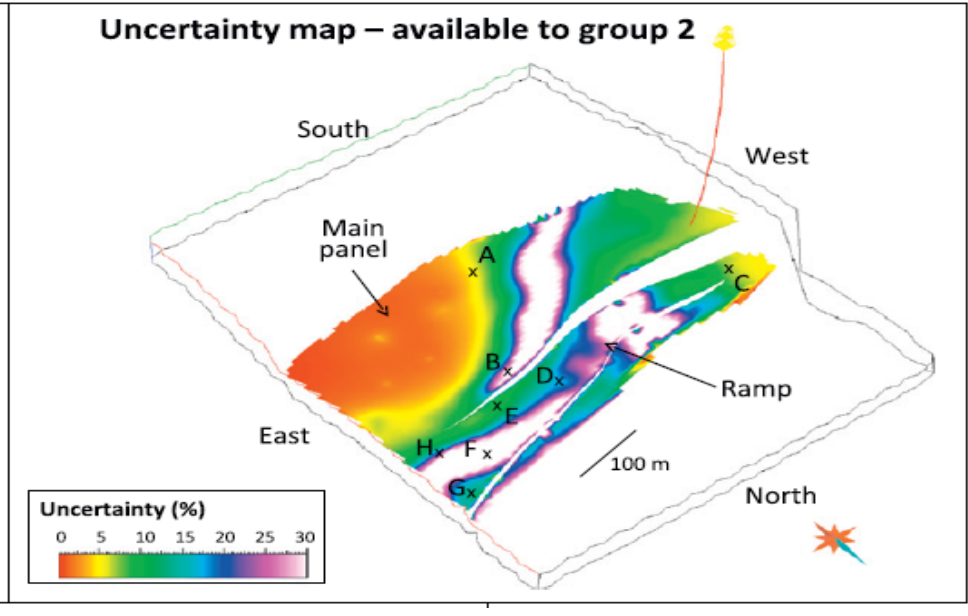




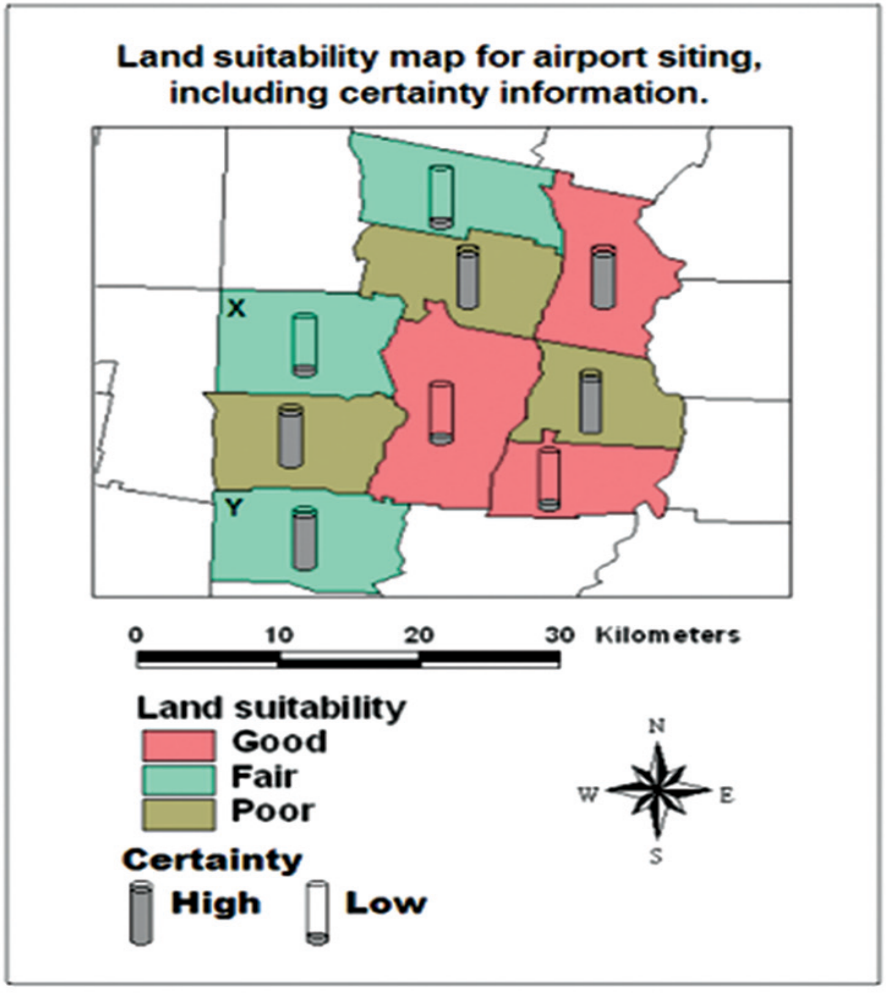
(Luboschik et al. 2010)

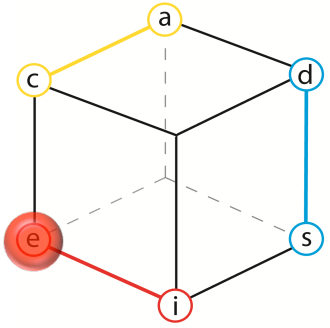




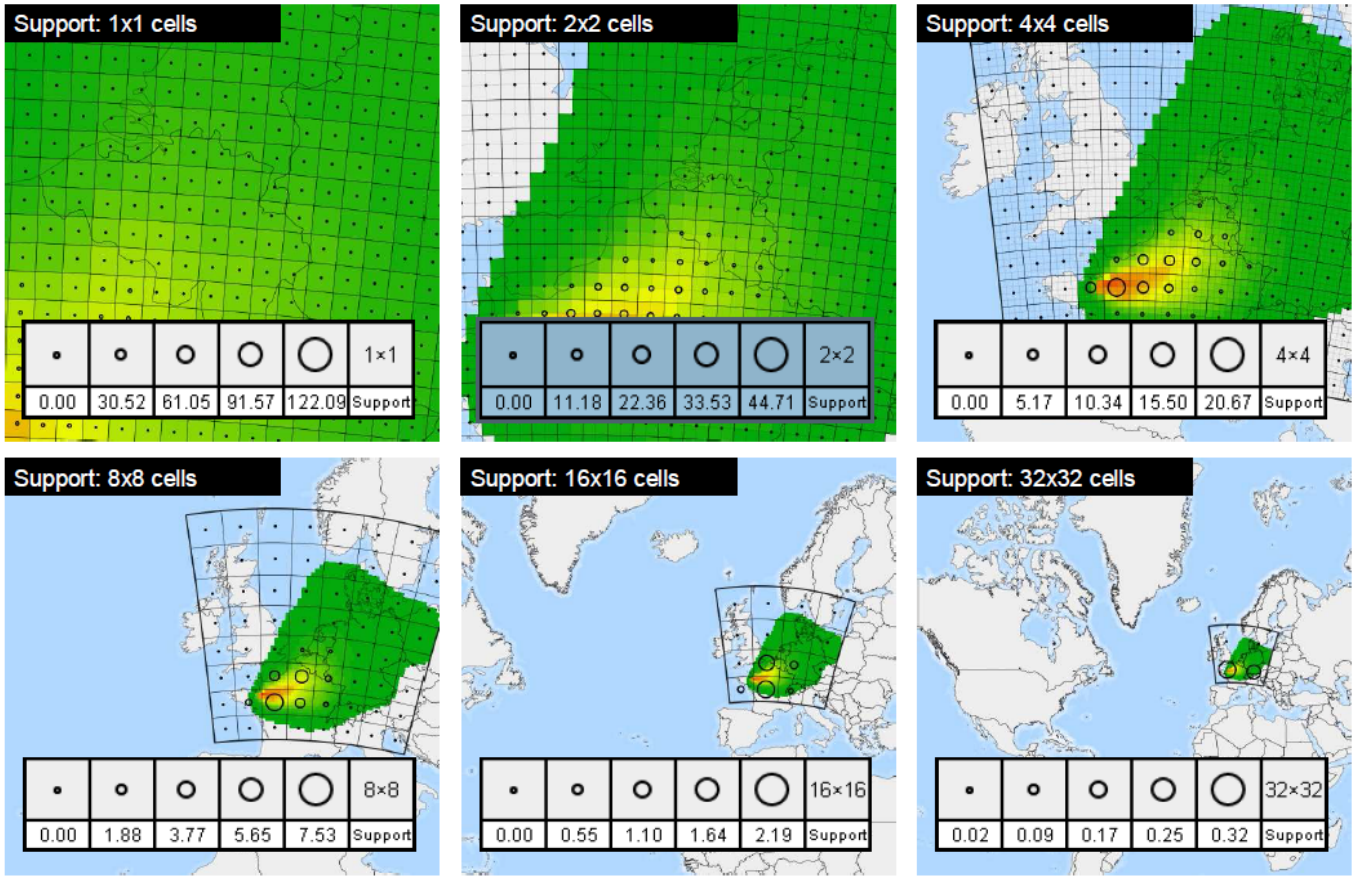


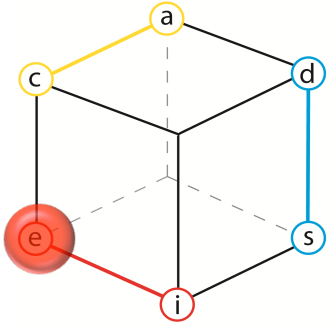
(Viard et al. 2011)



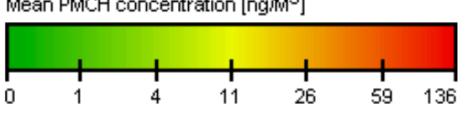


(Hope and Hunter, 2007)



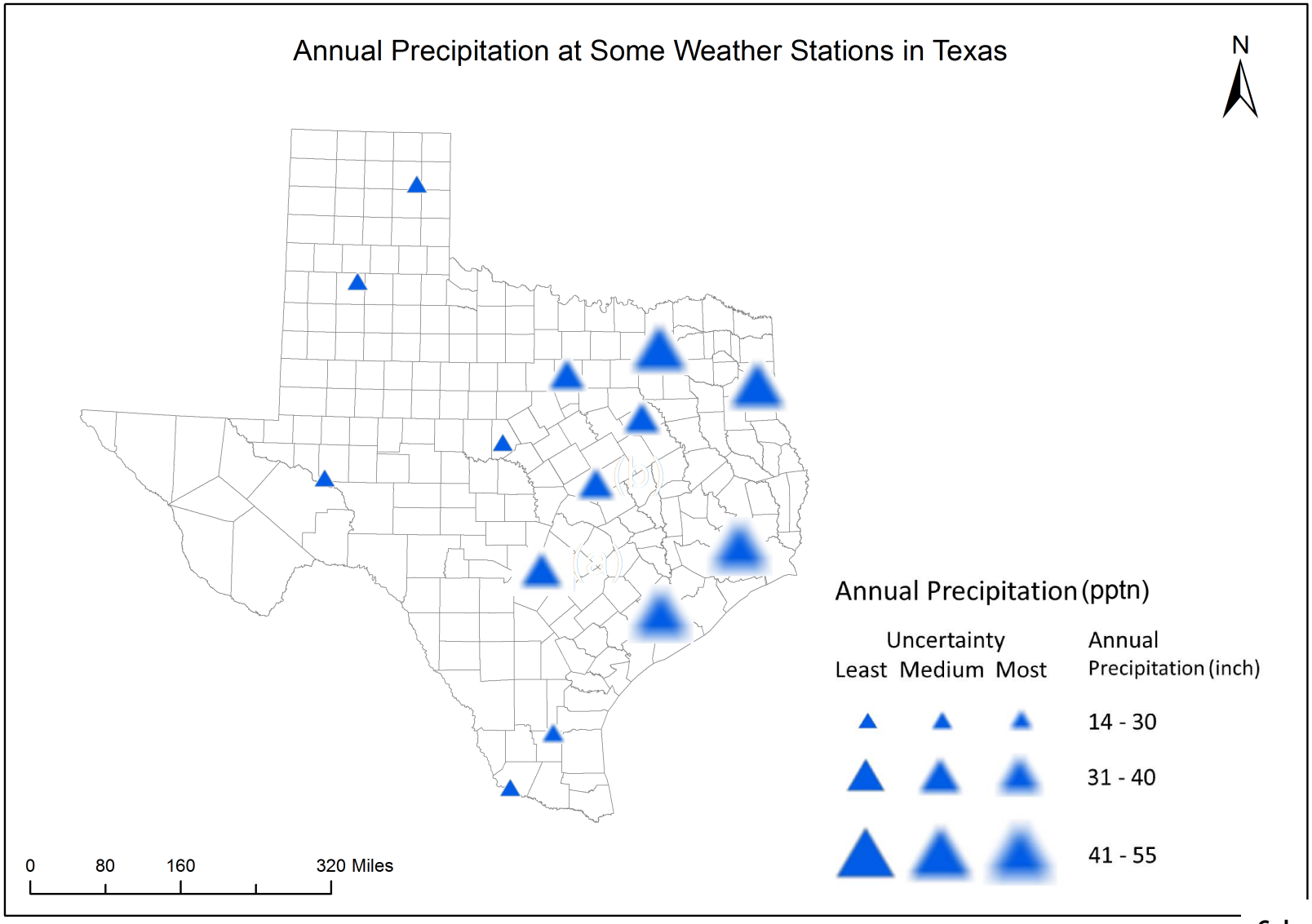


Ensemble mean of the PMCH concentration [µg/m³] in the sample dataset



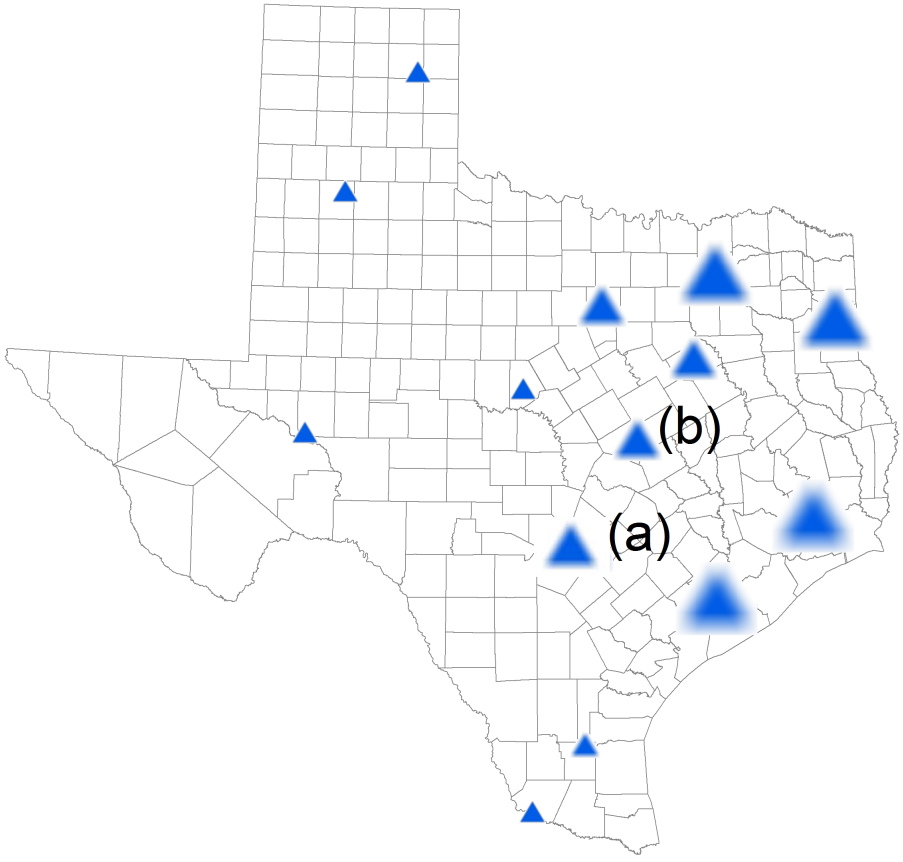
(Alberti 2013)

Part III / III: Usage of uncertainty



Scholz & Lu 2014

Annual Precipitation at Some Weather Stations in Texas

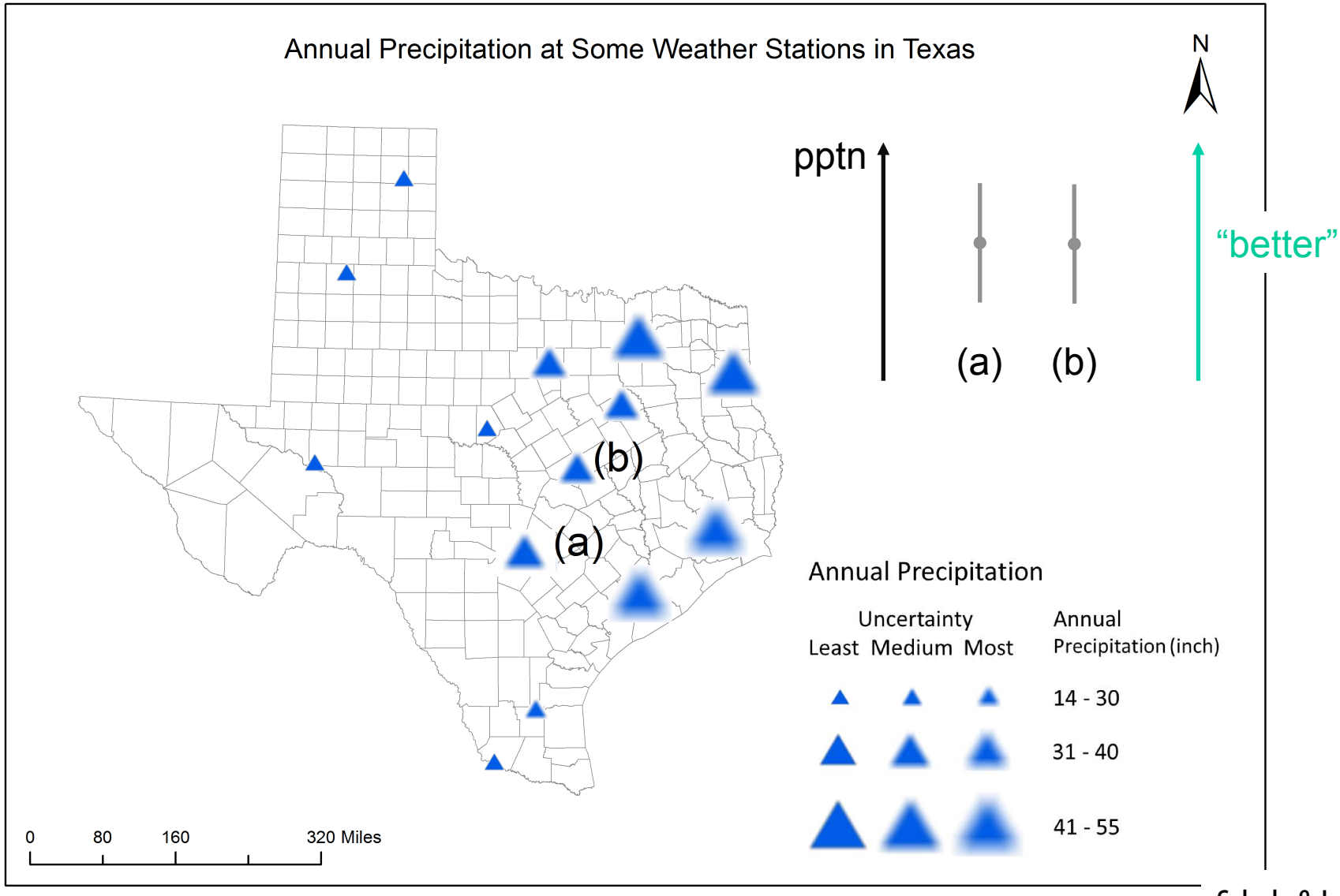


N

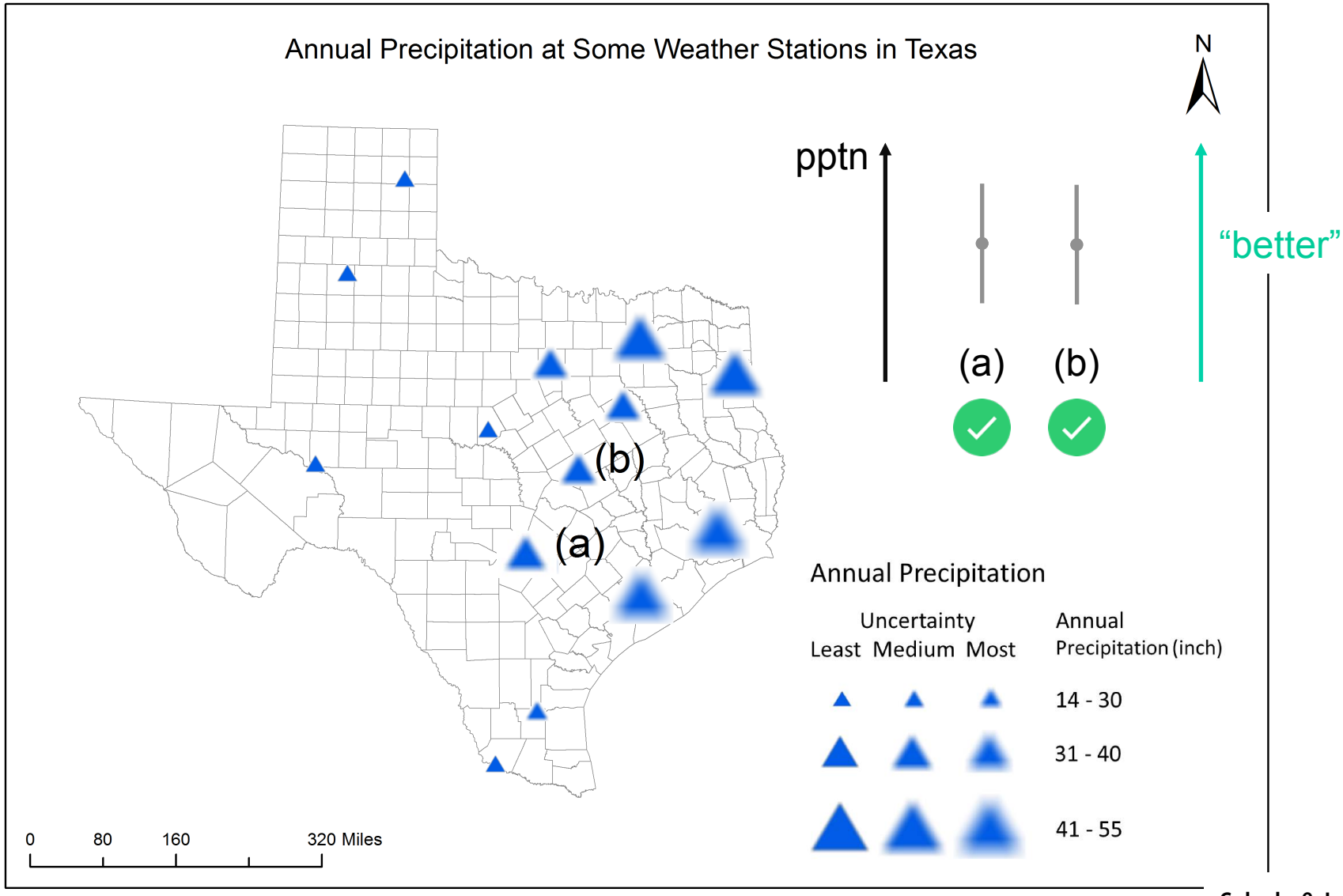
Annual Precipitation pptn

Uncertainty Least Medium Most	Annual Precipitation (inch)
▲ ▲ ▲	14 - 30
▲ ▲ ▲	31 - 40
▲ ▲ ▲	41 - 55

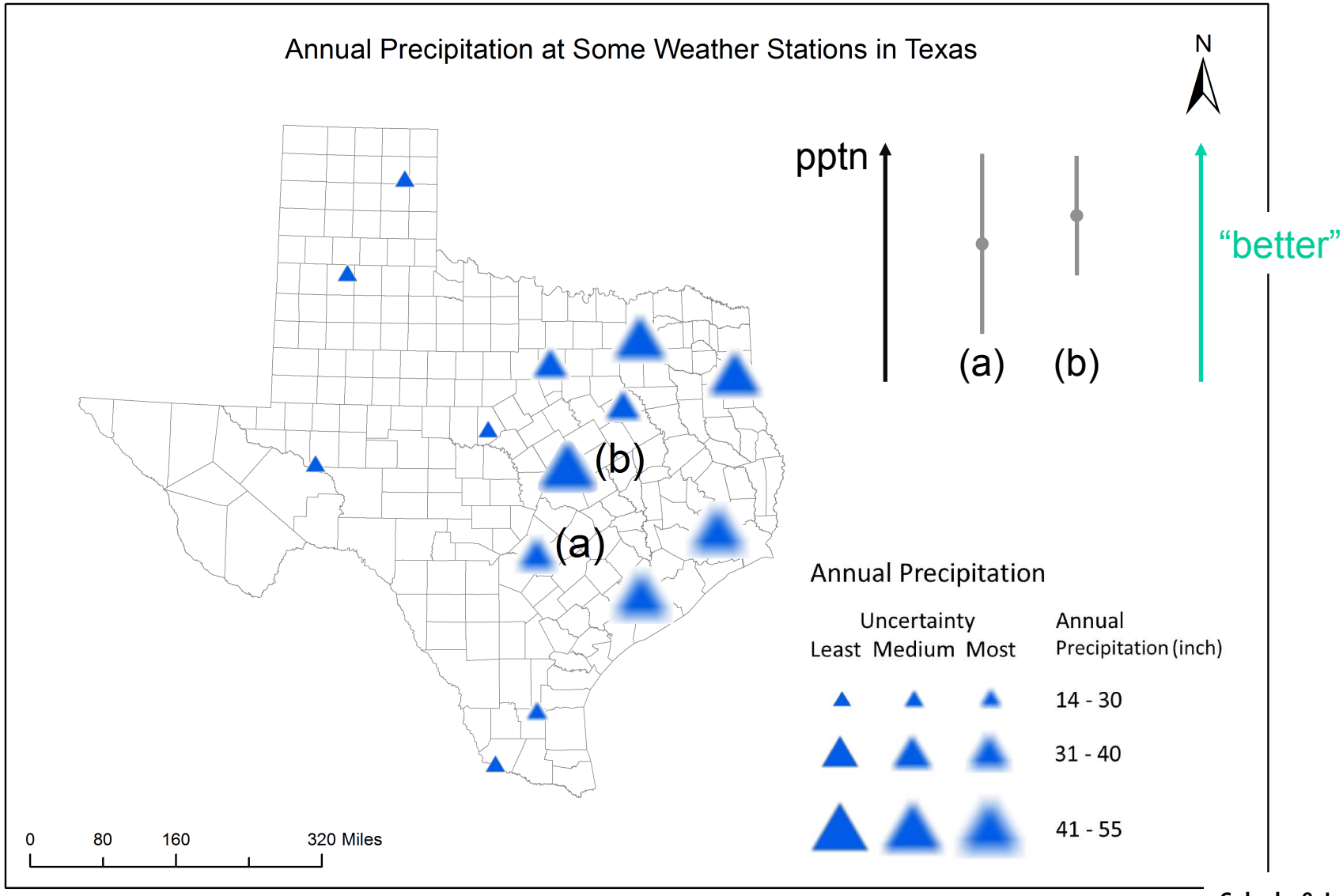
Scholz & Lu 2014



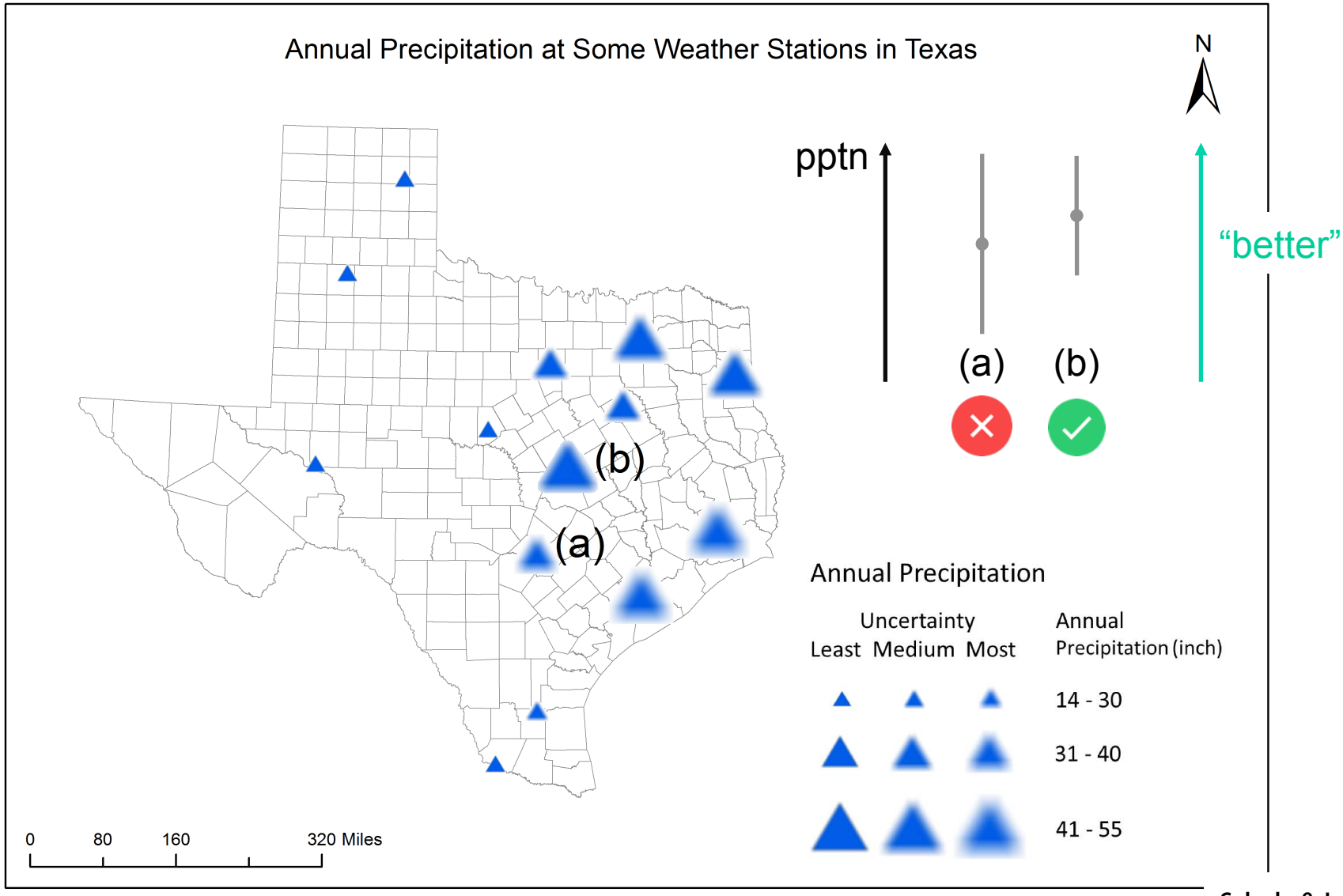
Scholz & Lu 2014



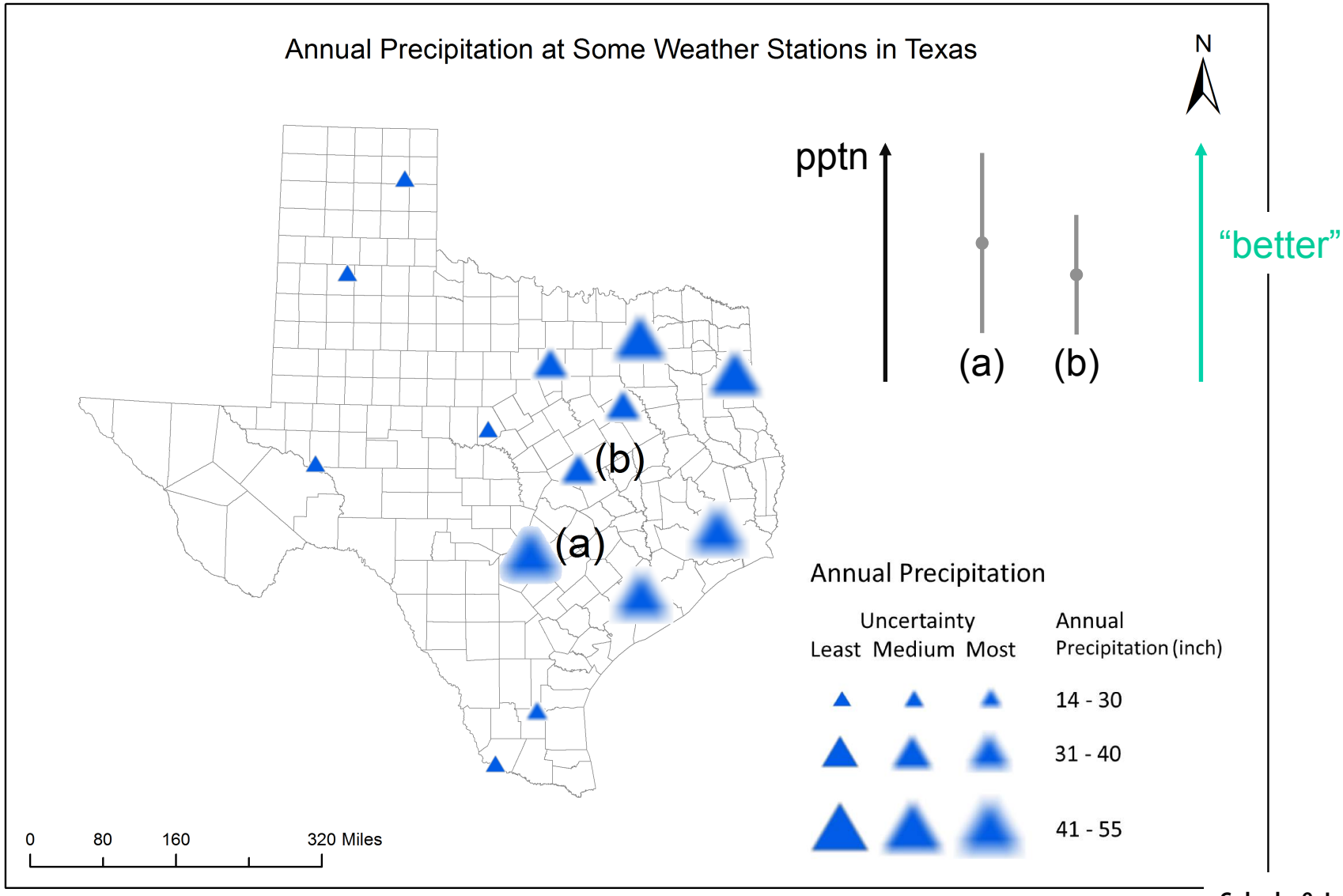
Scholz & Lu 2014



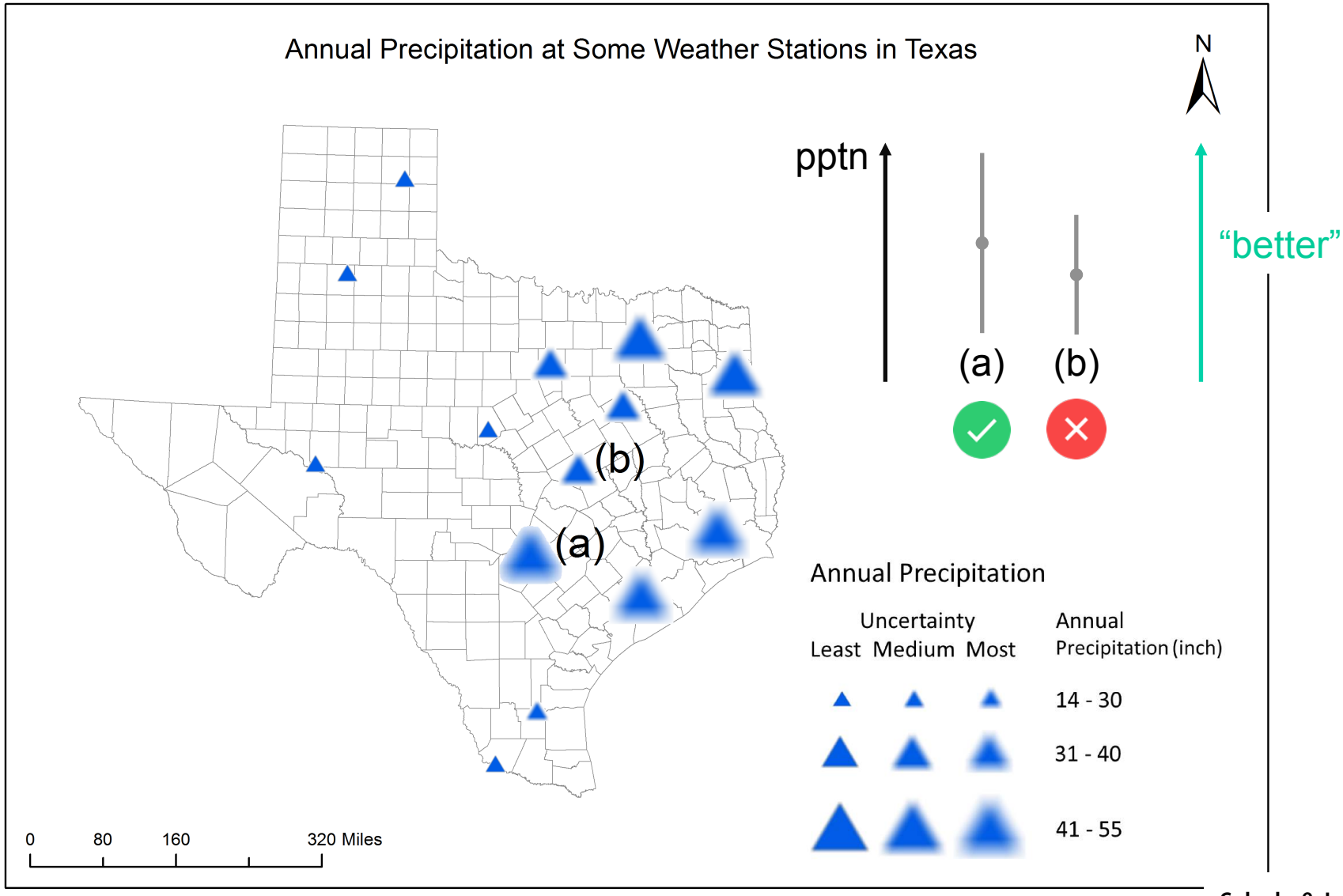
Scholz & Lu 2014



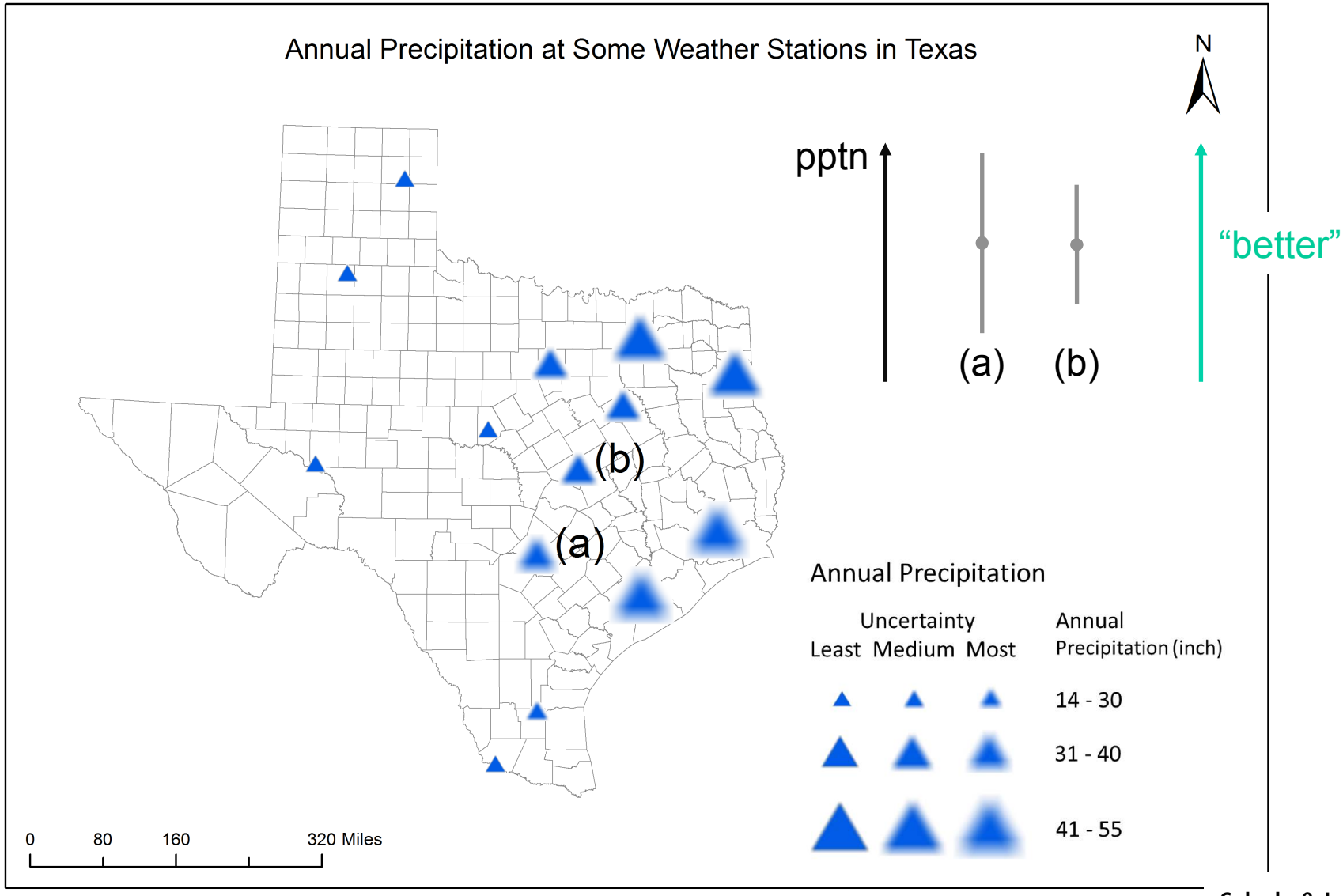
Scholz & Lu 2014



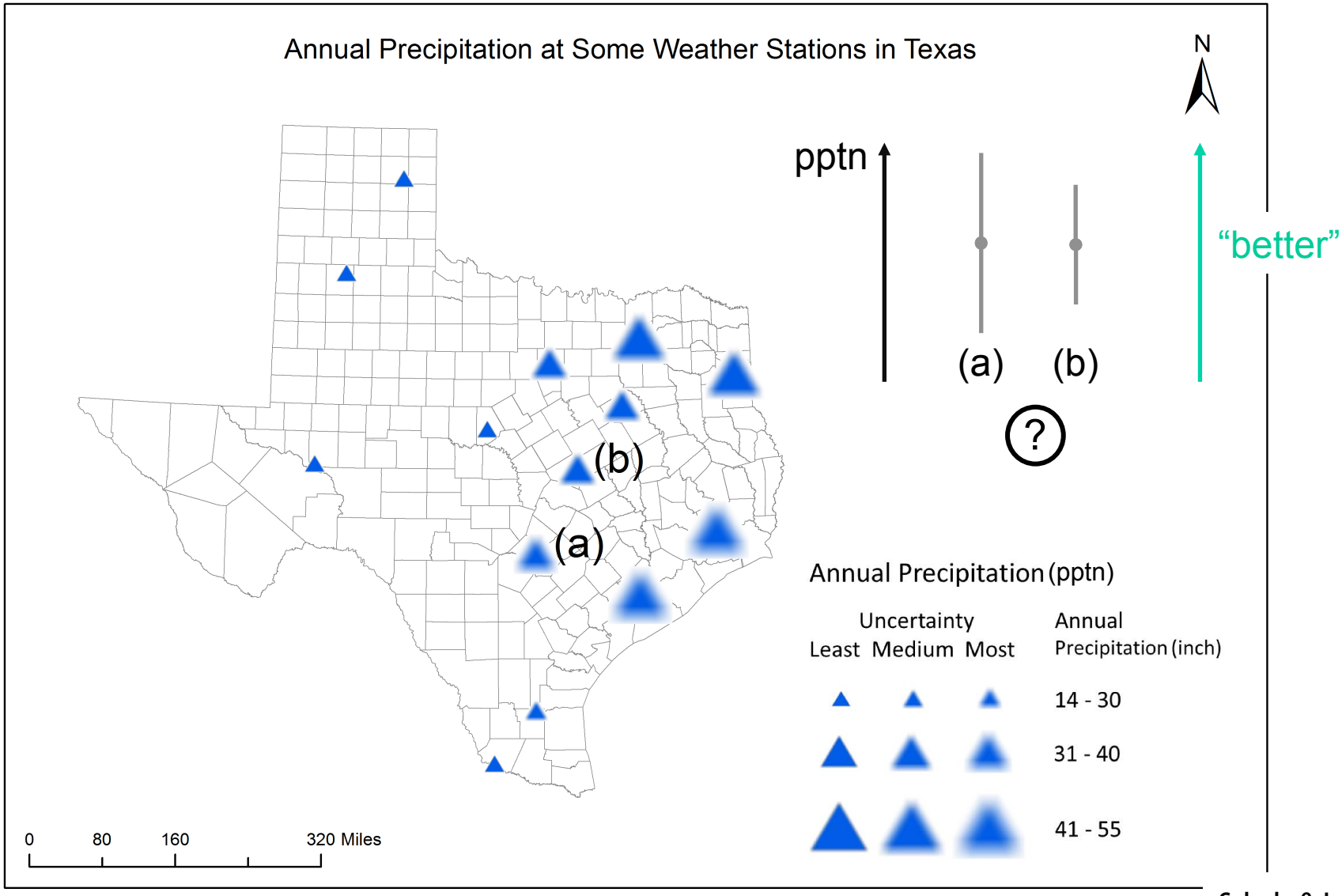
Scholz & Lu 2014



Scholz & Lu 2014



Scholz & Lu 2014



Scholz & Lu 2014

Uncertainty usage

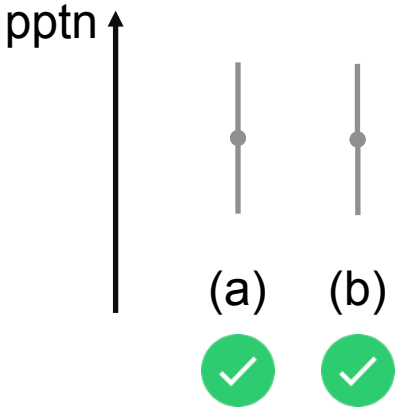
In order to use uncertainty information:

Users need to *understand* the meaning

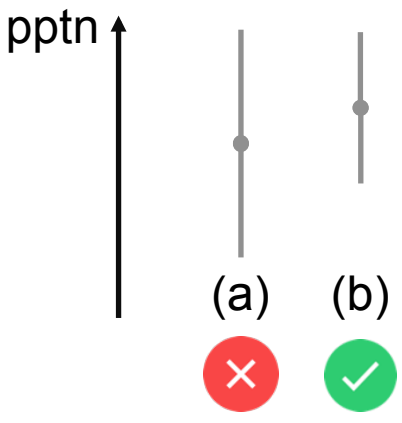
They need *guidelines* how to interpret
different levels of uncertainty

-> decision support systems (DSS) can support this

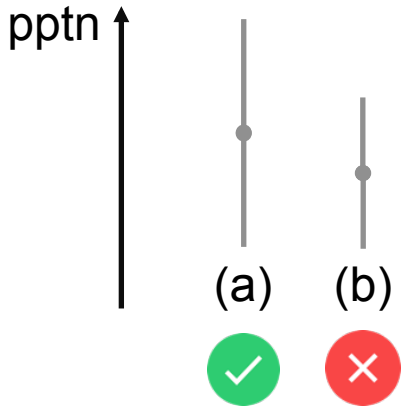
Decision support



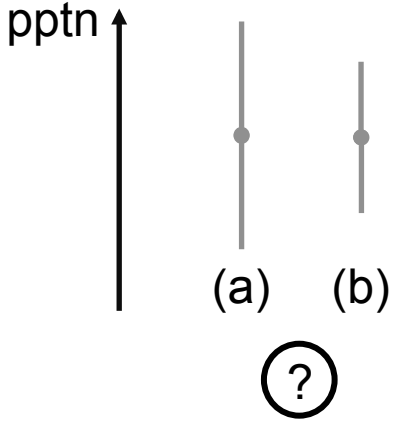
"Pick (a) or (b)"



"Pick (b)"



"Pick (a)"



"(a) might be better or worse than (b)"

Questions?

Find the references here: http://tiny.cc/va2017-ref

Hands on!

PM10 emissions: get the data

Particle pollution

PM10: inhalable particles of 10 micrometers and smaller

Get deeply into humans' lungs and even in bloodstream

Can cause serious health problems (asthma, lung cancer)

https://www.epa.gov/pm-pollution

Hands on!

A journalist is writing about the dangers of PM10 and what can be done politically on the European level to decrease the emission

For that she needs a map of PM10 emissions over Europe in the past

Let's GO!