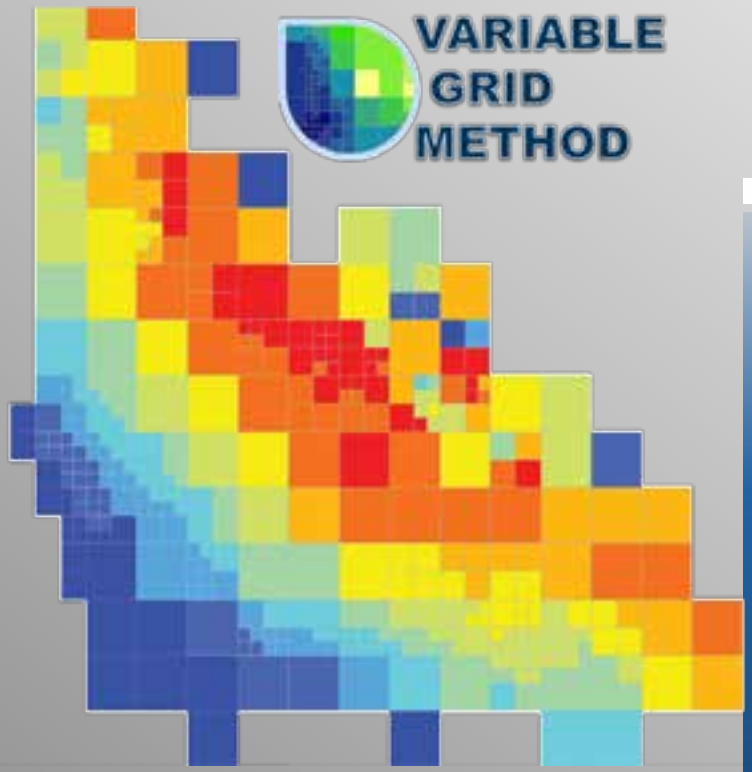


Variable Grid Method:

Using Uncertainty to Inform Spatial Decisions

2015 Esri International User Conference

Jennifer Bauer & Kelly Rose

National Energy Technology Laboratory

Increasing collection and access to spatial data

Photo from the Economist

As a result, a wide range of ***users*** and ***disciplines*** have begun incorporating spatial data

http://youtu.be/9vLa1HM1IKY (video)

Running into Uncertainty

Uncertainty in spatial data can stem from various sources:

- collection, processing, and/or analysis methods,
- spatial and/or temporal extent,
- data aggregation, etc.

In addition, uncertainty can refer various things, including:

accuracy	*precision*
error	*quality*
ambiguity	*reliability*

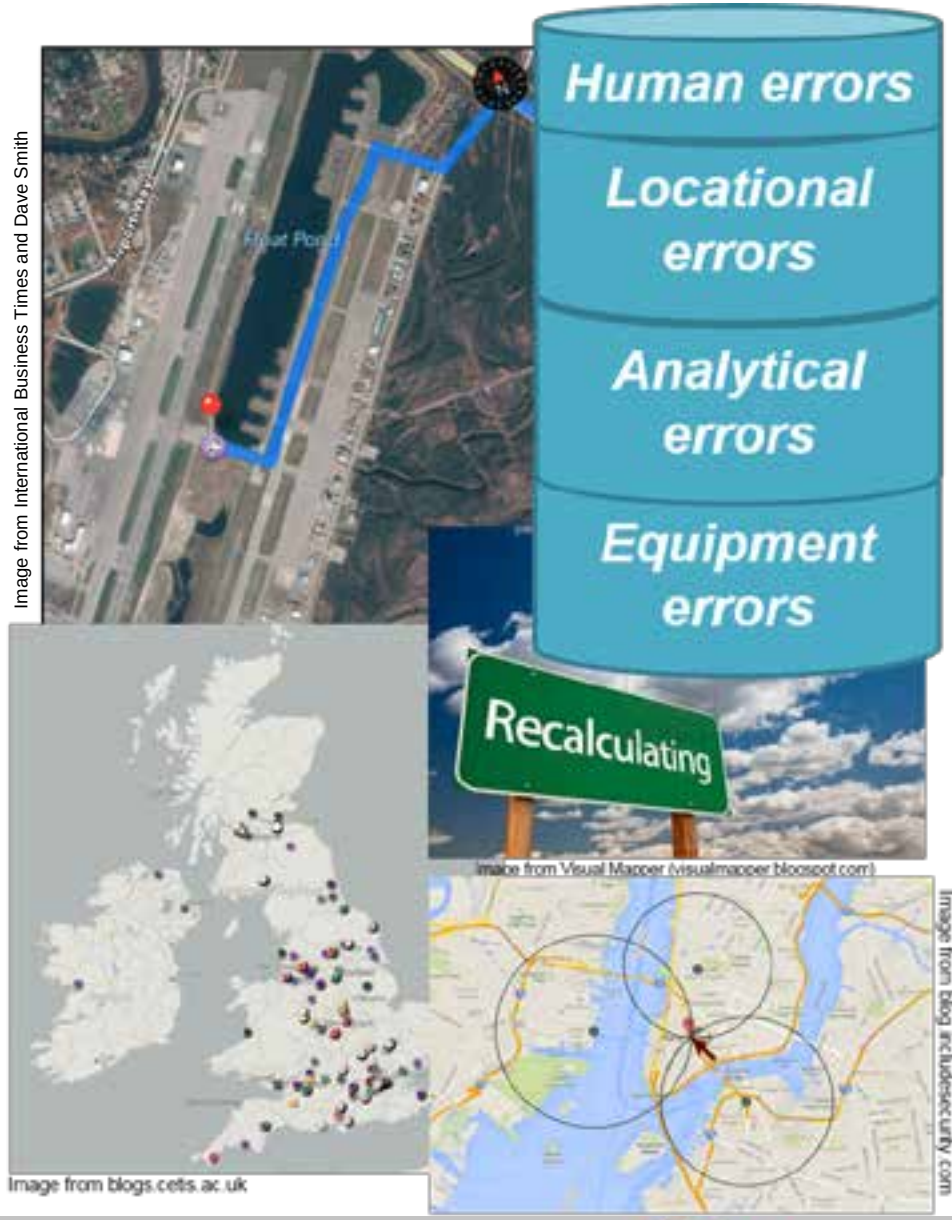


Image from International Business Times and Dave Smith

Image from Visual Mapper (visualmapper.blogspot.com)

Image from blogs.cetis.ac.uk

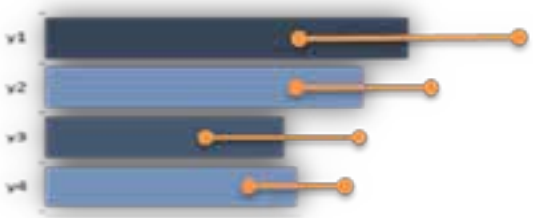
Image from blog.includesecurity.com

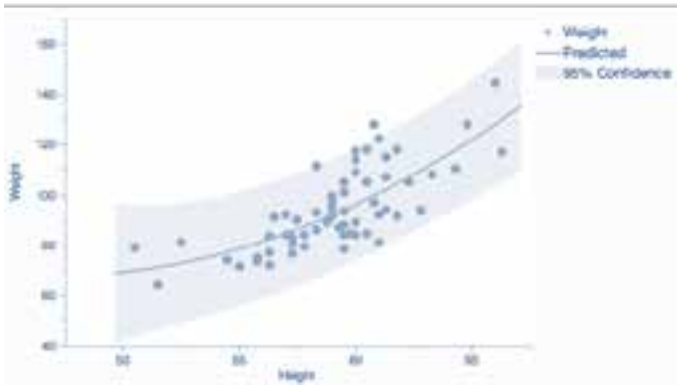
http://youtu.be/9vLa1HM1IKY (video)

Failing to Represent Uncertainty

Spatial data uncertainty information is often lacking due to difficulties:

- from variety of potential sources and definitions,
- visualizing uncertainty, and
- communicating results effectively to a broad range of users





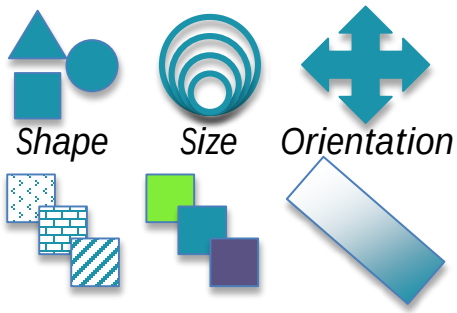
As the uses and applications for spatial data continues to increase so does the importance of ***effectively communicating uncertainty*** inherent to spatial data

Current Methods for Uncertainty

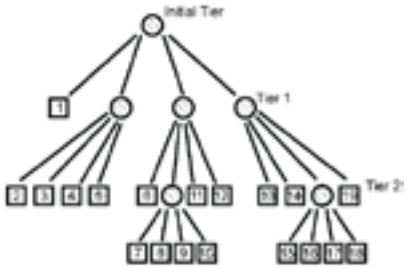
Several approaches have been developed to cope with uncertainty associated with spatial data, such as:

- defining factors and potential sources of uncertainty (e.g., metadata),
- developing qualitative and quantitative approaches to characterize and estimate, and
- creating visualization tools and methods to better communicate uncertainty

Visual Variables



Spatial Data Structures



Quadtree

Display Type

Static

Dynamic

http://youtu.be/9vLa1HM1IKY (video)

Limitations of current approaches

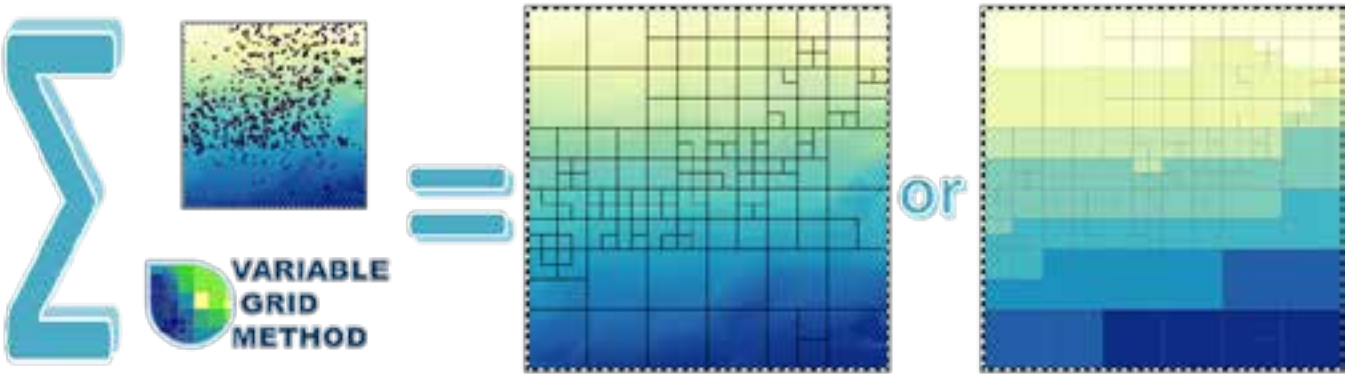
So why aren't these methods more broadly utilized?

- Lack flexibility regarding inputs
- Unable to customize outputs
- Disconnect with final audience

Failing to effectively communicating any underlying ***uncertainty*** can ***lead to false conclusions*** and ***poor decisions*** as well as ***affect the quality*** of current and future research and products

Variable Grid Method (VGM)

Designed to visualize spatial data and uncertainty simultaneously



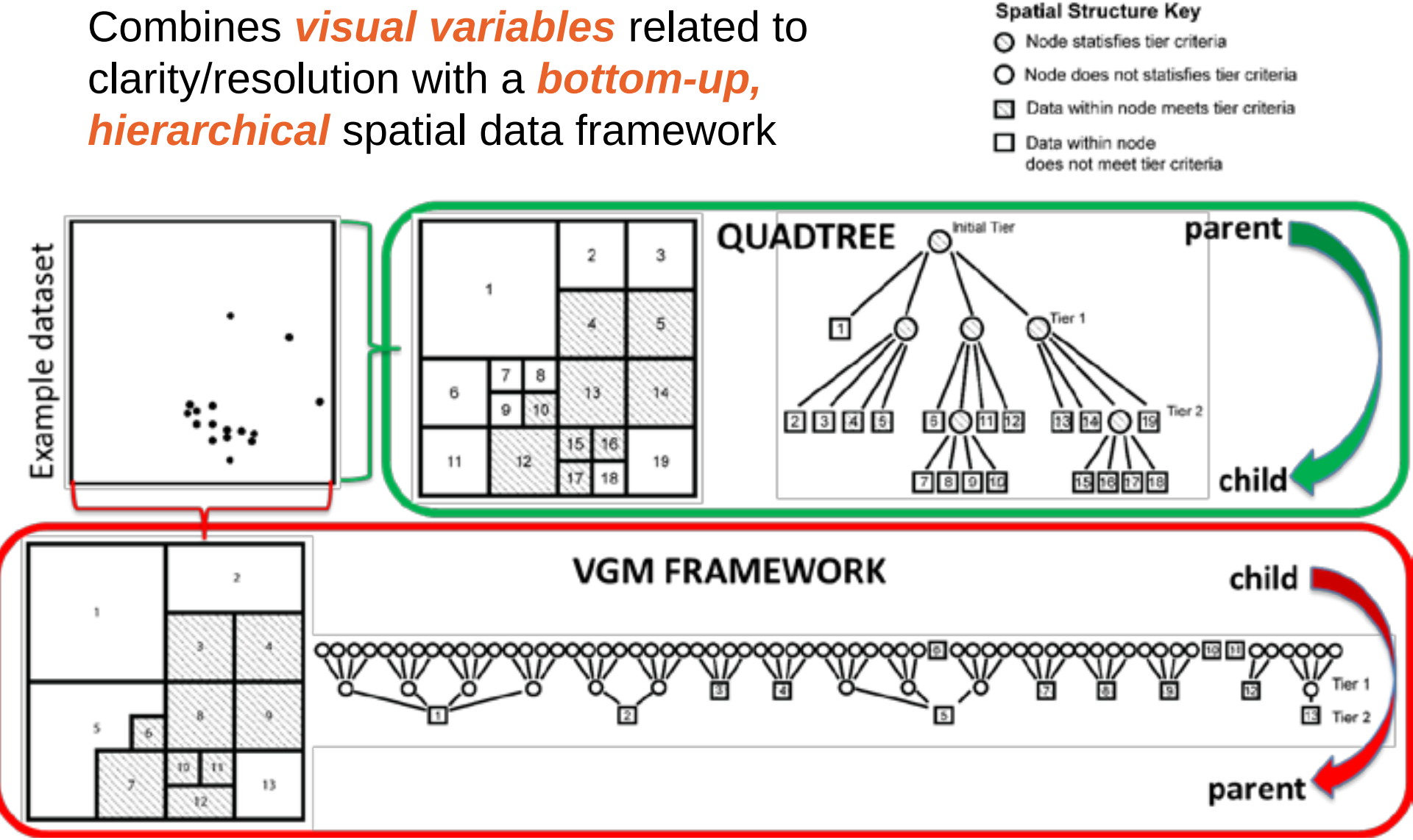
Communicate data (via colors) and uncertainty (via grid cell size)

This approach:

- allows the ***flexibility*** to use different data types and uncertainty quantifications
- preserves ***overall spatial trends and patterns*** observed within the data
- enables users to ***customize*** the final product to meet their needs and best communicate results in an ***intuitive manner***

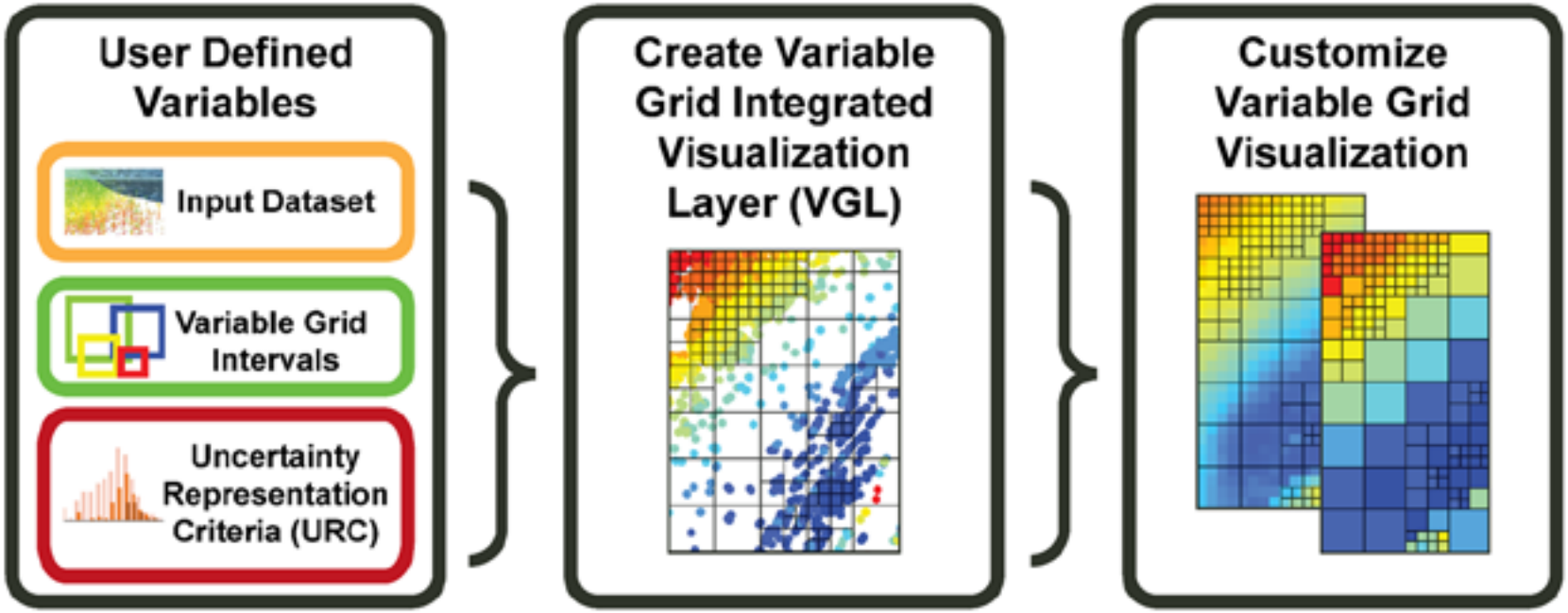
How the VGM Works

Combines ***visual variables*** related to clarity/resolution with a ***bottom-up, hierarchical*** spatial data framework



http://youtu.be/9vLa1HM1IKY (video)

User-driven Approach



Input Datasets can be in a variety of formats and types

Variable Grid Cell Intervals (VGCI) define what size your grid cells will be and how many intervals will be included in the final VGL

Uncertainty Representation Criteria (URC) defines what grid cell size is kept

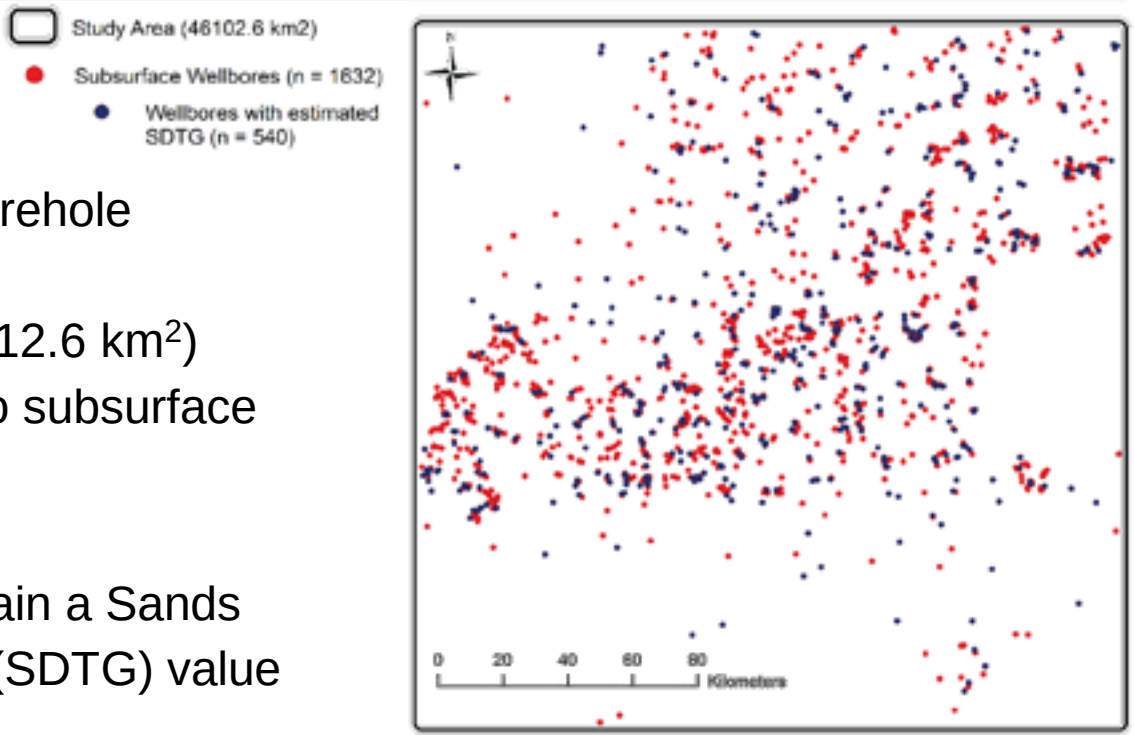
VGM Example

Let's use the VGM to create two variable grid integrated visualization layers (VGL) using:

- the ***same*** input dataset,
- the ***same*** variable grid cell intervals (VGCI),
- but ***different*** uncertainty representation criteria (URC)

Input Dataset

- 2013 BOEM Sands and Borehole Datasets
- Utilized a subset area (46012.6 km^2)
- Several attributes related to subsurface characteristics
- Total records = 1632
  - Only 540 records contain a Sands Temperature gradient (SDTG) value



VGM Example – Determining VGCIs

Variable grid cell intervals (VGCIs) can be set based off various data, including:

- expert knowledge,
- statistical analytical results, and
- common practices, etc.

VGCIs for this example were set to:

3 intervals at 9 x 9, 18 x 18,

and 36 x 36 km

based off a combination of spatial statistic results (NN, Moran's I and Ripley's K)

Nearest Neighbor (NN)

NN Observed	1455.7 m
NN Ratio	0.548
***z*-score**	-34.9
***p* value**	< 0.001

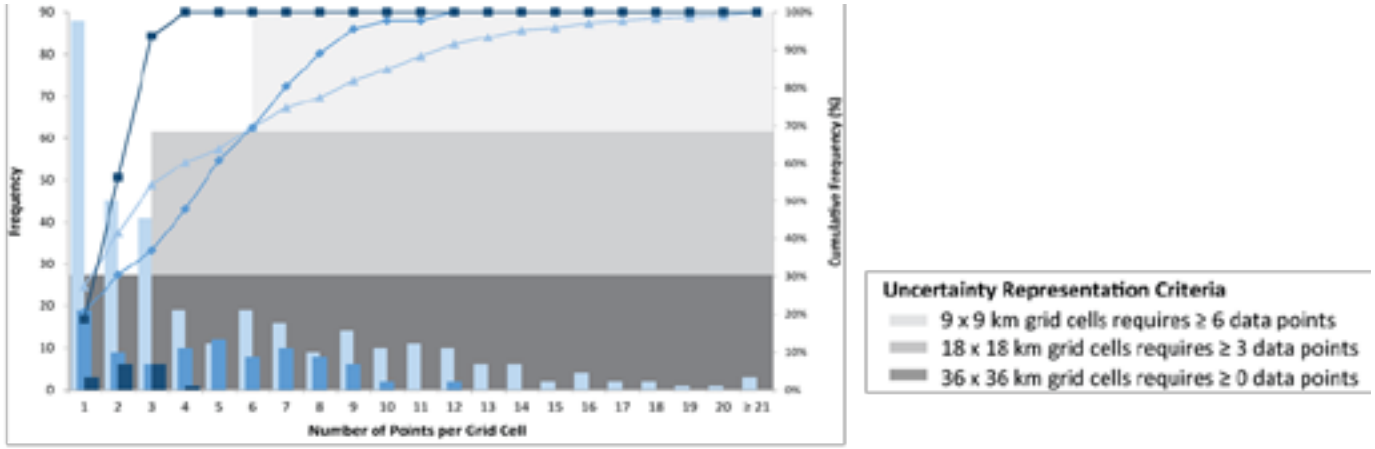
Moran's I

Distance (m)	Moran's Index (I)	Expected Index	Variance	z-score	p-value
2500	0.313961	-0.000831	0.000436	11.315604	< 0.001
	0.337863	-0.003876	0.001377	9.048875	< 0.001
10000	0.113646	-0.000620	0.000079	12.832162	< 0.001
	0.468717	-0.001901	0.000722	17.549337	< 0.001
14000	0.097562	-0.000615	0.000046	14.515445	< 0.001
	0.376688	-0.001893	0.000394	19.062013	< 0.001
18000	0.090981	-0.000615	0.000029	17.095637	< 0.001
	0.374579	-0.001808	0.000244	23.965179	< 0.001
21500	0.078773	-0.000614	0.000020	17.727189	< 0.001
	0.322266	0.001896	0.000179	24.342857	< 0.001
42500	0.060228	-0.000613	0.000006	25.788946	< 0.001
	0.223518	-0.001855	0.000044	33.309802	< 0.001

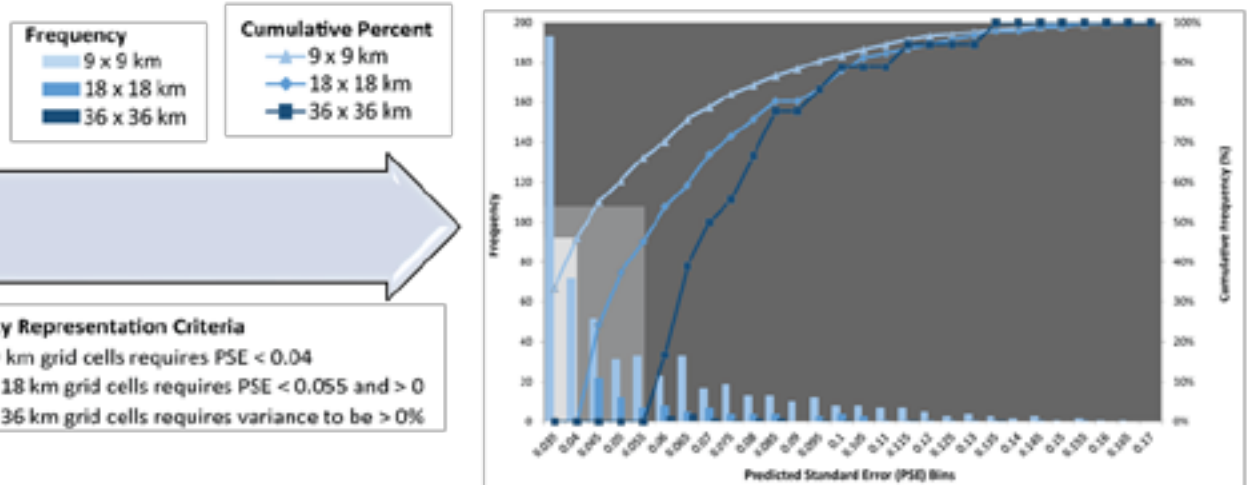
VGM Example – Using different URCs

Various uncertainty quantifications can be used to determine the URC – we'll focus on 2 different data quantities that can represent uncertainty

Sample Density

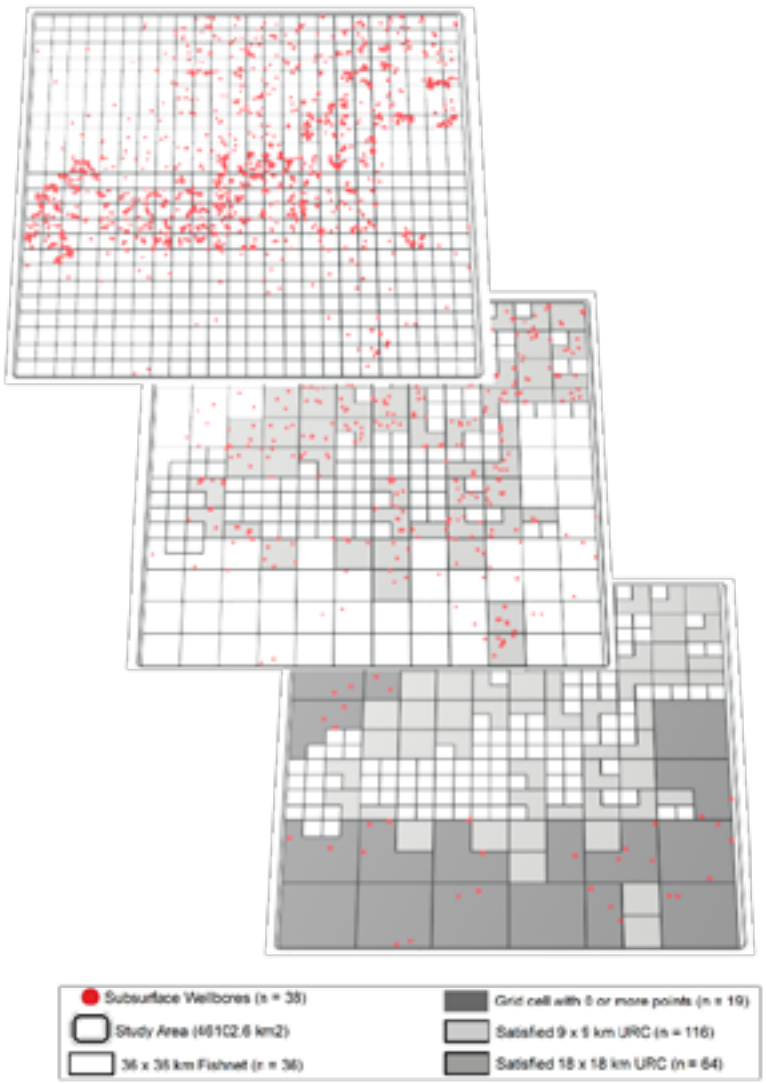


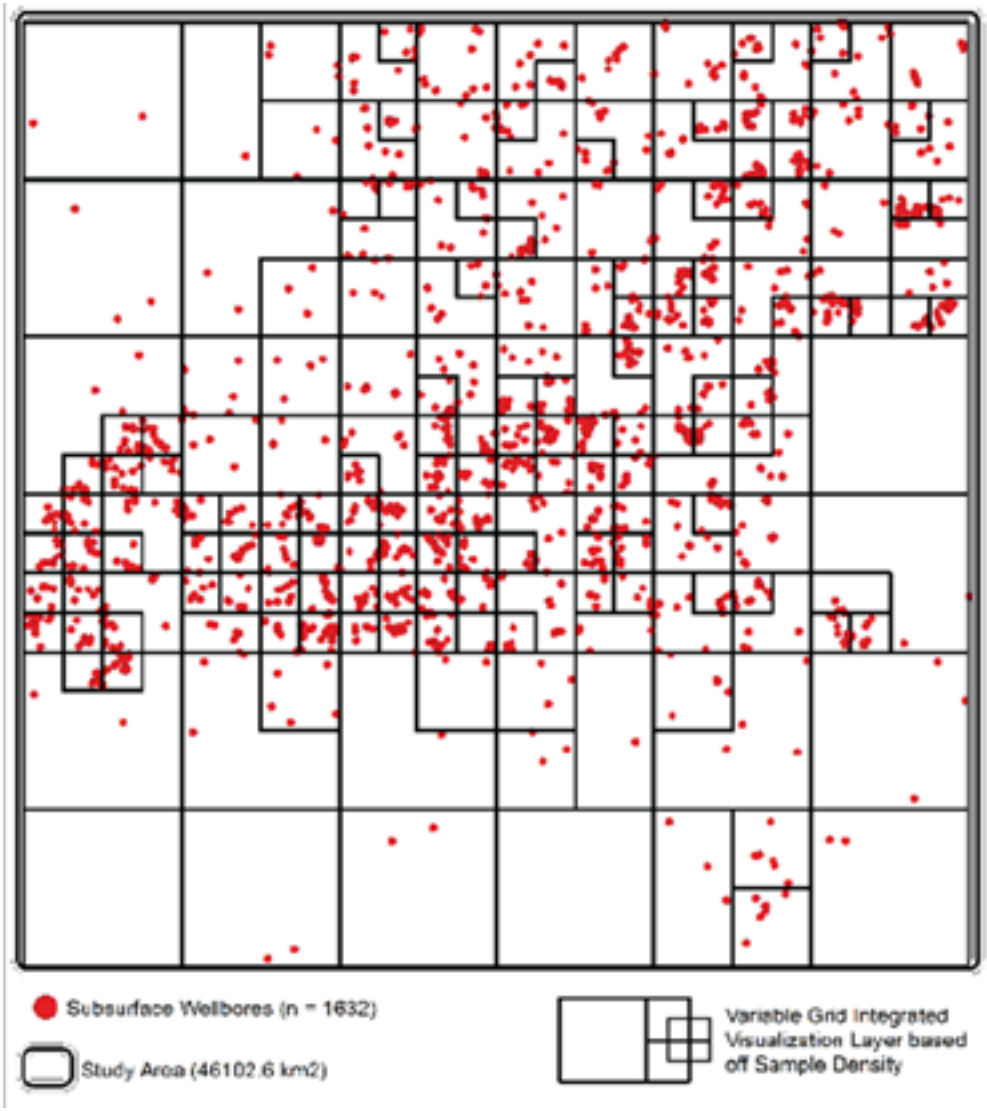
Interpolation Standard Error



http://youtu.be/9vLa1HM1IKY (video)

Sample Density





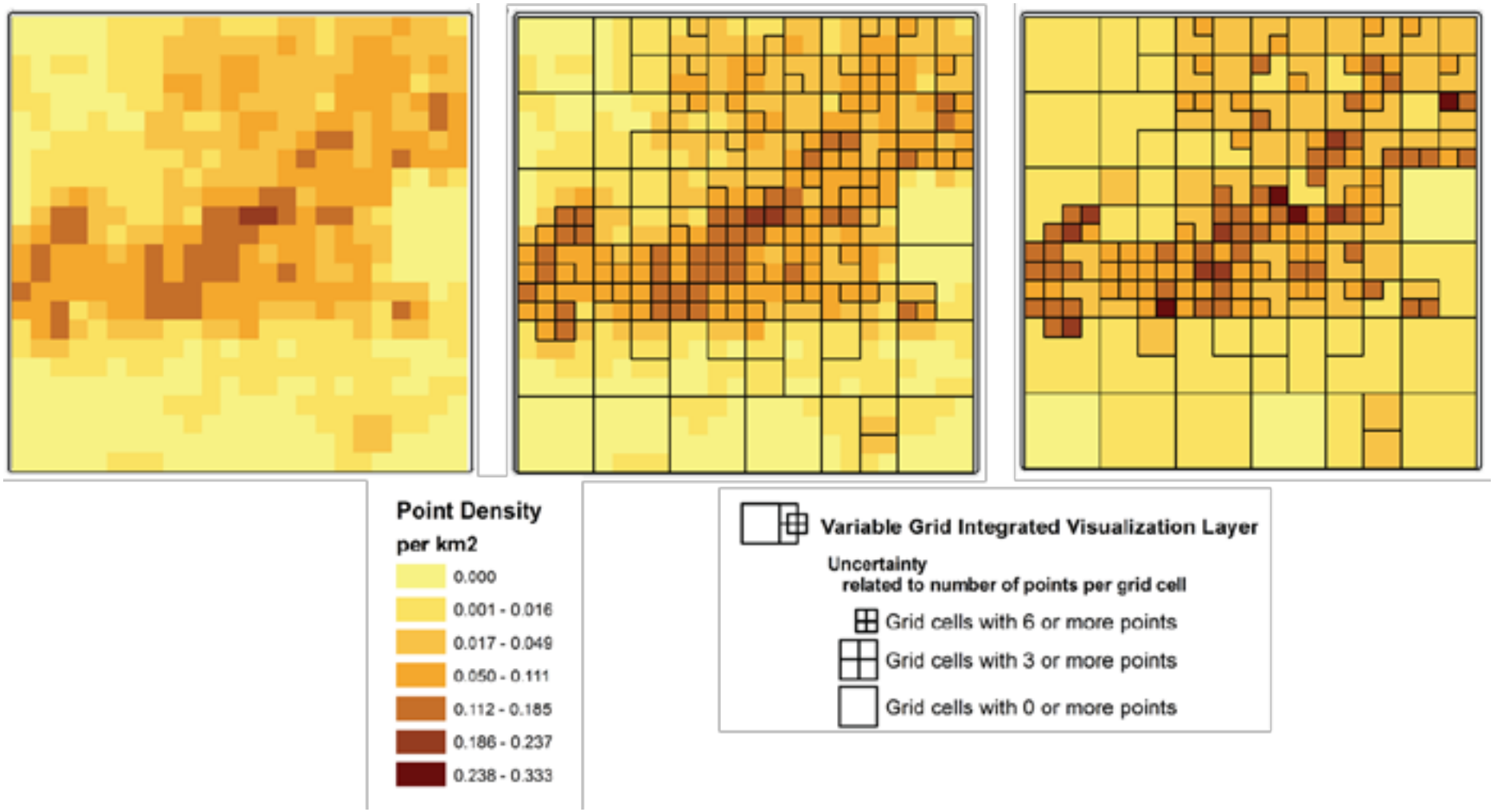
http://youtu.be/9vLa1HM1IKY (video)

Sample Density

Interpolated Point Density

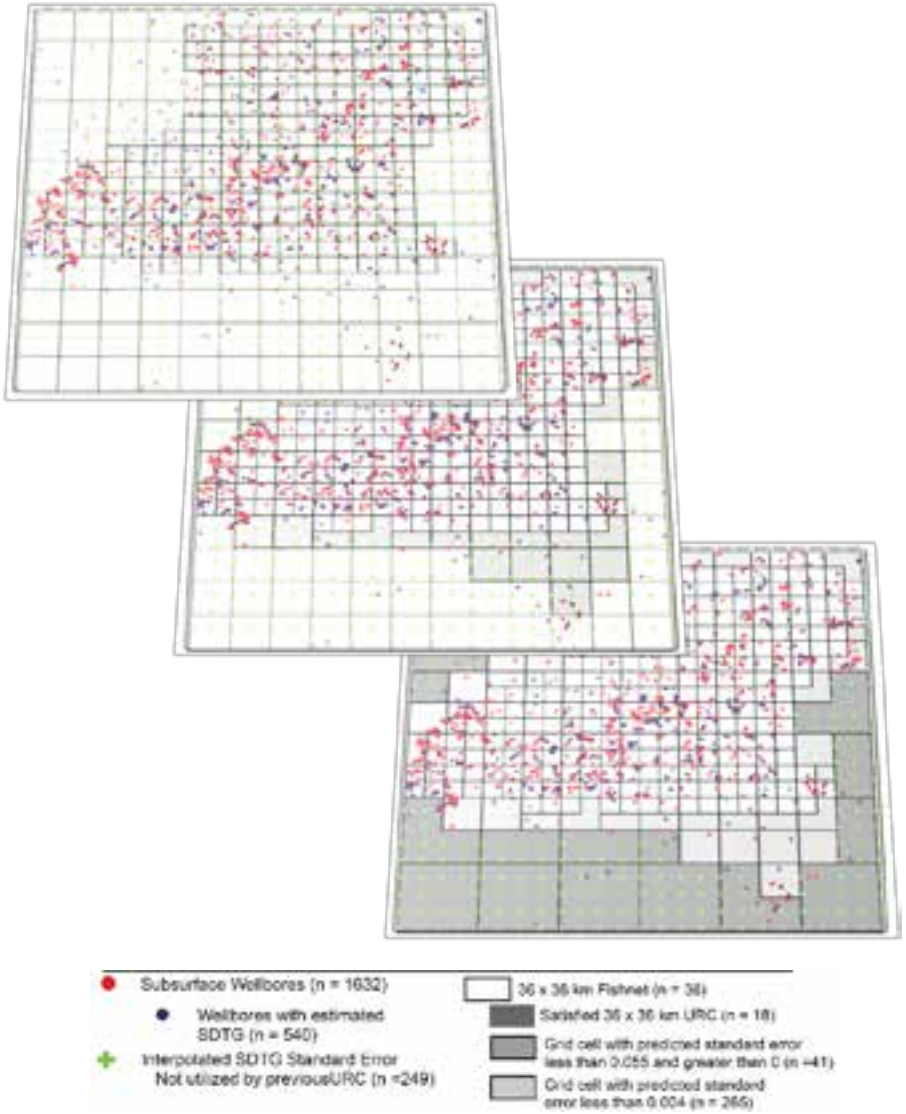
Interpolated Point Density with VGM Overlay

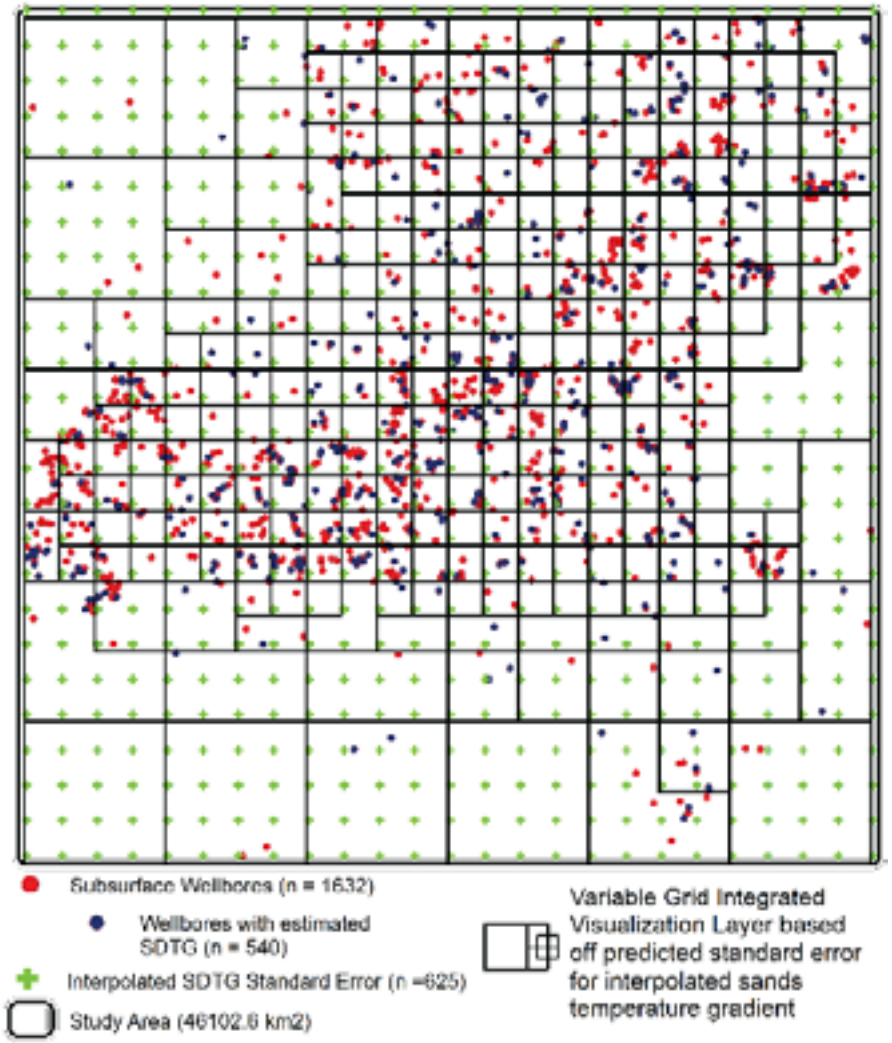
Avg. Point Density with VGM Integration



http://youtu.be/9vLa1HM1IKY (video)

Interpolation Standard Error





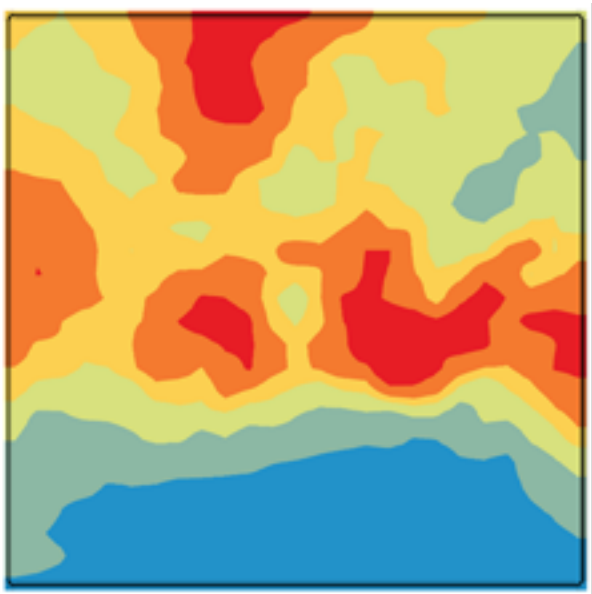
http://youtu.be/9vLa1HM1IKY (video)

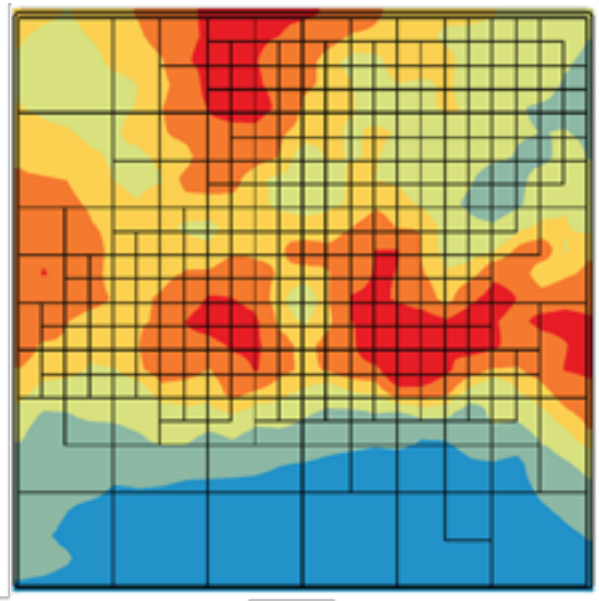
Interpolation Standard Error

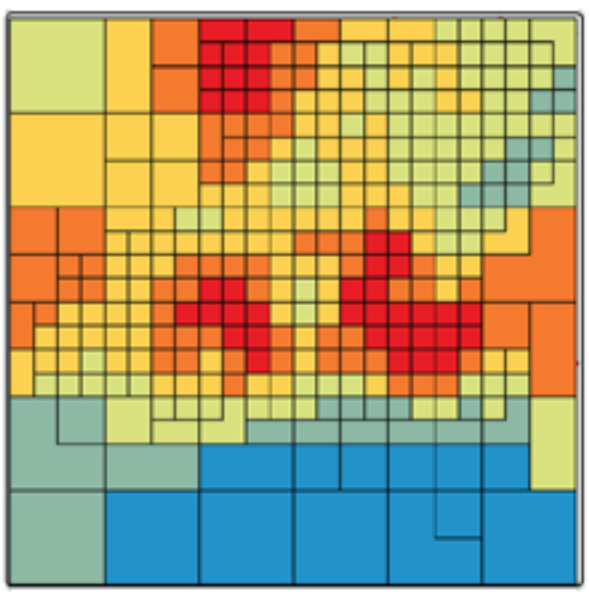
Interpolated Avg. Sand Temperature Gradient

Interpolated Avg. Sand Temperature Gradient with VGM Overlay

Avg. Sand Temperature Gradient with VGM Integration







Average Sand Temperature Gradient (SDTG)

°F/100 ft.

- 0.82 - 1.08
- 1.09 - 1.23
- 1.24 - 1.32
- 1.33 - 1.38
- 1.39 - 1.46
- 1.47 - 1.62

Variable Grid Integrated Visualization Layer

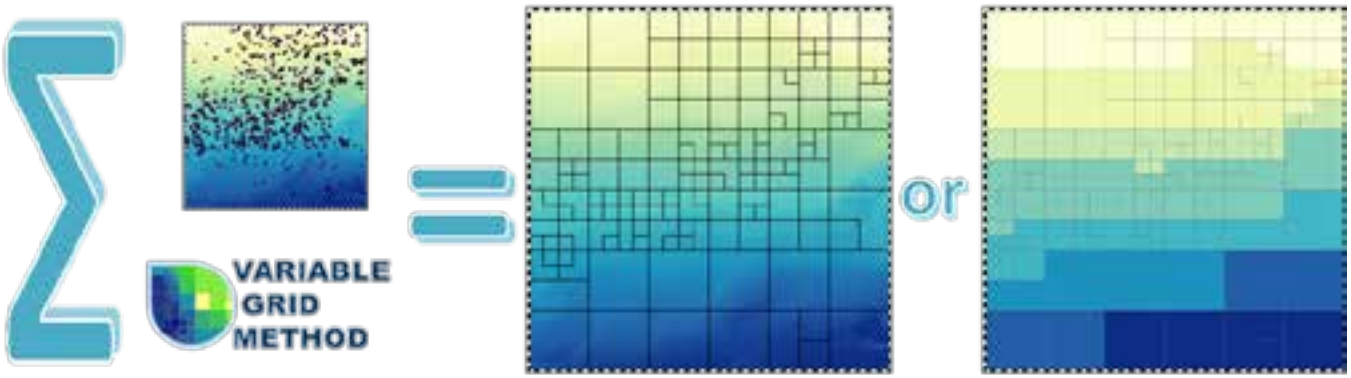
Uncertainty
related to predicted standard error (PSE)
for sand temperature gradient
per grid cell

- Grid cell with PSE less than 0.004 (n = 265)
- Grid cell with PSE less than 0.055 and greater than 0 (n =41)
- Grid cell not previous selected (n =18)

http://youtu.be/9vLa1HM1IKY (video)

Key Takeaways

VGM presents uncertainty with spatial data in an ***intuitive manner*** so it can be ***effectively used*** to support various decision-making needs

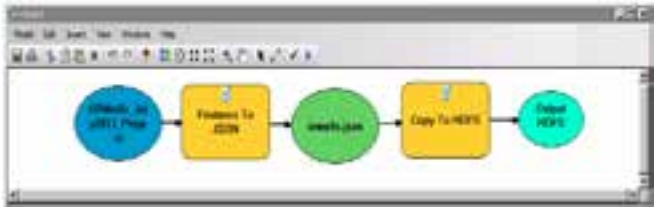


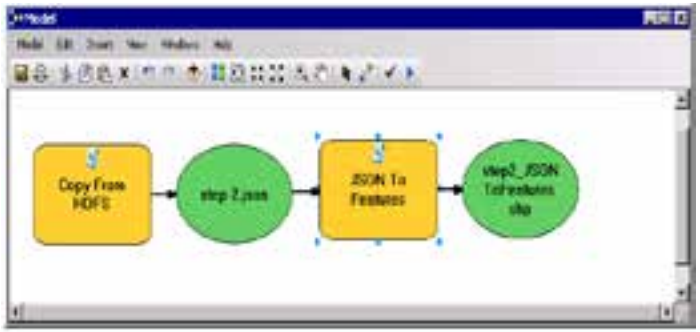
Provides the needed ***flexibility*** to use different data types and uncertainty quantifications and allows ***customization*** of the final product to meet the needs of various users, from a range of background and disciplines

Next Steps

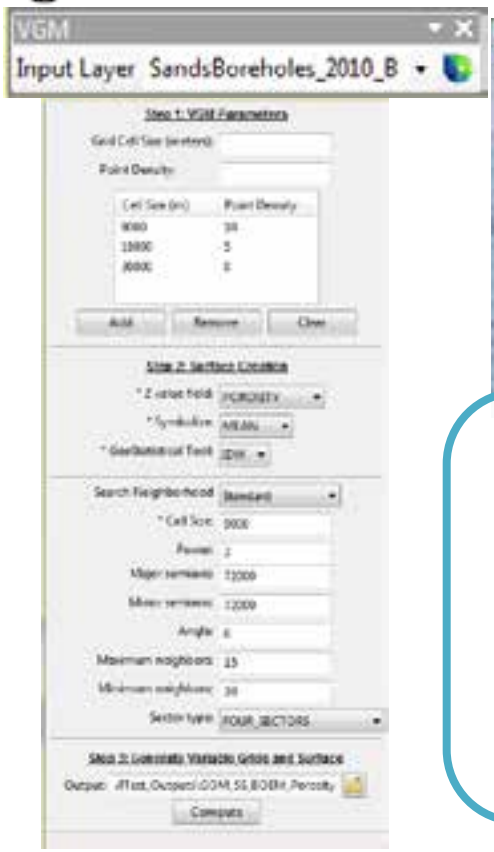
Efforts for the VGM will now focus on:

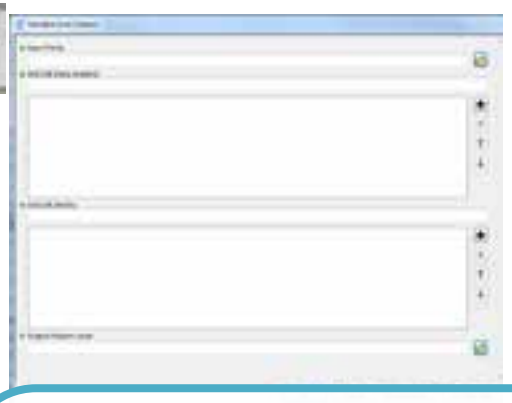
- Broaden applications and testing
- Tool development and release





esri ArcGIS Add-in





Interested in the Arc Add-in?

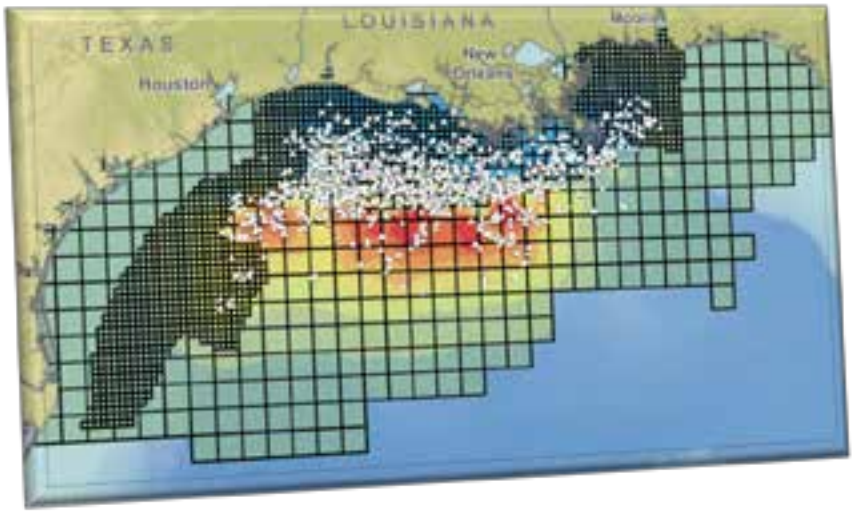
Check out the presentation!

Using wxPython in Desktop Python Add-in for Variable Grid Method Tool

Wednesday @ 3:15pm

Thank you!

VARIABLE GRID METHOD



Jennifer Bauer

jennifer.bauer@contr.netl.doe.gov

AECOM Geospatial Researcher

Kelly Rose

kelly.rose@netl.doe.gov

Geologist and Geology & Geospatial Team Lead

Bauer, J., and Rose, K., 2015, Variable Grid Method: an Intuitive Approach for Simultaneously Quantifying and Visualizing Spatial Data and Uncertainty, *Transactions in GIS*. 19(3), p. 377-397

EDX A Product of NETL

For more information on the VGM check out some of the links below:
http://www.netl.doe.gov/File%20Library/Research/onsite%20research/R-D201-2015Apr.pdf
http://youtu.be/9vLa1HM1IKY