Variable Grid Method:
Using Uncertainty to Inform Spatial Decisions

Jennifer Bauer & Kelly Rose
National Energy Technology Laboratory
Increasing collection and access to spatial data

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

http://youtu.be/9vLa1HM1IKY (video)
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 to various things, including:

- accuracy
- error
- precision
- quality
- ambiguity
- reliability

[Image from International Business Times and Dave Smith]
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

http://youtu.be/9vLa1HM1jKY (video)
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
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

\[ \sum \text{VARIABLE GRID METHOD} = \text{Communicate data (via colors) and uncertainty (via grid cell size)} \]

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

http://youtu.be/9vLa1HM1IKY (video)
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 km²)
- Several attributes related to subsurface characteristics
- Total records = 1632
  - Only 540 records contain a Sands Temperature gradient (SDTG) value

[Video](http://youtu.be/9vLa1HM1IKY)
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)

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>NN Observed</td>
<td>1455.7 m</td>
</tr>
<tr>
<td>NN Ratio</td>
<td>0.548</td>
</tr>
<tr>
<td>z-score</td>
<td>-34.9</td>
</tr>
<tr>
<td>p value</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

Moran’s I

<table>
<thead>
<tr>
<th>Distance (m)</th>
<th>Moran’s Index</th>
<th>Expected Index</th>
<th>Variance</th>
<th>z-score</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2500</td>
<td>0.313563</td>
<td>-0.008831</td>
<td>0.0000466</td>
<td>11.315094</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>10000</td>
<td>0.113646</td>
<td>-0.000020</td>
<td>0.000079</td>
<td>12.331626</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>14000</td>
<td>0.0697562</td>
<td>-0.000015</td>
<td>0.0000494</td>
<td>13.315448</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>18000</td>
<td>0.0090815</td>
<td>-0.000015</td>
<td>0.0000209</td>
<td>17.095633</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>21500</td>
<td>0.078773</td>
<td>-0.000014</td>
<td>0.0000020</td>
<td>17.273177</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>42500</td>
<td>0.223918</td>
<td>-0.001456</td>
<td>0.0000446</td>
<td>11.009062</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

http://youtu.be/9vLa1HM1IKY (video)
Various uncertainty quantifications can be used to determine the URC – we’ll focus on 2 different data quantities that can represent uncertainty.
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

[Video Link: http://youtu.be/9vLa1HM1IKY]
Interpolation Standard Error

Interpolated Avg. Sand Temperature Gradient

Interpolated Avg. Sand Temperature Gradient with VGM Overlay

Avg. Sand Temperature Gradient with VGM Integration

http://youtu.be/9vLa1HM1JKY (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.

[http://youtu.be/9vLa1HM1IKY](http://youtu.be/9vLa1HM1IKY) (video)
Next Steps

Efforts for the VGM will now focus on:

- Broaden applications and testing
- Tool development and release

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

http://youtu.be/9vLa1HM1IKY (video)
Thank you!

Jennifer Bauer
jennifer.bauer@contr.netl.doe.gov
AECOM Geospatial Researcher

Kelly Rose
kelly.rose@netl.doe.gov
Geologist and Geology & Geospatial Team Lead


For more information on the VGM check out some of the links below:
http://youtu.be/9vLa1HM1IKY