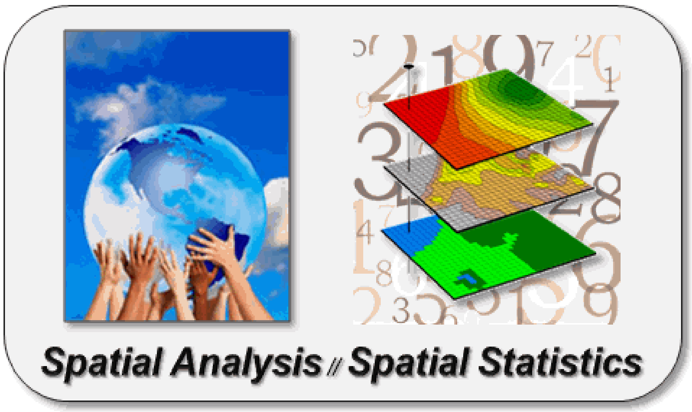
<u>SpatialSTEM</u>: a mathematical/statistical framework for understanding and communicating map analysis and modeling

National Geospatial-Intelligence Agency

St. Louis Facility — April 30, 2013

(with video-teleconference to NGA in Springfield, VA)



<u>Premise</u>: There is a "map-*ematics*" that extends traditional math/stat concepts and procedures for the quantitative analysis of map variables (spatial data)

A half-day intermediate workshop providing experience with the concepts, underlying theory, data considerations, procedures, and practical considerations in applying advanced grid-based map analysis techniques.

All of the workshop materials are posted at
www.innovativegis.com/basis/Workshops/NGA2013/

Presented by

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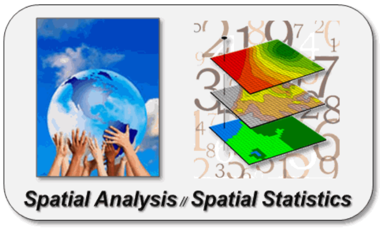
***SpatialSTEM**: a mathematical/statistical framework for understanding and communicating grid-based map analysis and modeling*



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Background

STEM is an acronym that stands for Science, Technology, Engineering, and Mathematics that identifies an educational approach designed to transform instruction by more seamlessly integrating the fields into regular curricula within a problem-solving, discovery, exploratory learning environment that actively engages students in finding solutions. SpatialSTEM extends traditional quantitative data analysis operations to the consideration of geographic location (where) as well as characteristics/conditions (what) in the analysis of mapped data. Within this context, grid-based map analysis and modeling reaches far beyond its traditional mapping and geo-query roles (technical tool) into a radically new role that promises to change how we perceive and utilize quantitative data analysis in all STEM disciplines (analytical tool).

Spatial Analysis** and **Spatial Statistics form a relatively new set of tools for quantitative analysis that cuts across a multitude of disciplines and applications. At its foundation is the perspective that "*maps are numbers first, pictures later*" and that there is a comprehensive "map-ematics" extending traditional mathematics and statistics as a means to better understand spatial patterns and relationships. These fundamental analysis tools build upon the STEM foundation in a manner analogous to statistics and matrix algebra as extensions to traditional mathematics at the turn of the last century.

For example, the calculation of slope and aspect in terrain analysis is actually a spatial extension of the mathematical derivative with numerous applications outside of traditional mapping, such as calculating the slope of a barometric surface to derive a map of wind speed (high winds where pressure is rapidly changing), while its aspect map identifies wind direction. Similarly, calculating the slope of a cost surface to derive a marginal cost surface identifying where costs are rapidly changing; its aspect identifies the direction of maximum change at every map location.

While there have been great strides in implementing STEM-based education in K-12 classrooms, its adoption in higher education has been less successful. The cross-cutting nature of *Spatial*STEM provides a common foundation in mathematics and statistics for analyzing spatial data that can help bridge the disciplinary silos and stimulate interdisciplinary interaction.

Workshop Goal and Objectives

This workshop provides a fresh perspective in interdisciplinary collaboration and communication by combining the philosophy and approach of *STEM* with the spatial reasoning and analytical power of *Grid-based Map Analysis and Modeling*. Upon completion of the workshop participants will develop a basic understanding of the—

- advantages/disadvantages of discrete (point, line, polygon) and continuous (surface) mapped data,
- analytical capabilities of grid-based *Spatial Analysis* and *Spatial Statistics*, and
- future directions in quantitative analysis of mapped data.

The workshop is intended for geospatial professionals wanting to understand and communicate map analysis capabilities with non-GIS professionals. The material is presented in the vernacular of the STEM community using examples building on the common language of math/stat. Spatial reasoning principles and procedures are demonstrated through several cross-cutting "mini-case studies." All of the workshop materials are posted at www.innovativegis.com/basis/Courses/NGAworkshop/. In addition, related materials including software for "hands-on" exercises are posted at www.innovativegis.com/Basis/Courses/SpatialSTEM/.

Workshop Schedule:

Overview (.5 hour). This presentation is open to all GIS and non-GIS personnel interested in an overview of map analysis and modeling that should be of general interest to all NGA analysts, GIS specialists, scientists, management and staff interested in better understanding the potential and pitfalls of quantitative map analysis. The presentation thesis is that there is a mathematical structure for understanding and communicating map analysis operations that provides a common foothold in understanding the concepts, procedures and considerations that resonate with both non-GIS and GIS communities. Similarly, the final session on *Future Directions* are appropriate for general audiences.

Spatial Analysis (1.5 hours). Modern digital maps are “numbers first, pictures later.” In map-*ematical* processing, these data can be conceptualized as a set of "floating maps" with a common registration that enables the computer to "look" down and across the stack of map layers to spear or corral sets of numbers for processing. *Spatial Analysis* involves quantitative analysis of the “spatial context” of mapped data, such as add, subtract, multiply, divide, exponentiation, root, log, cosine, differentiate and even integrate maps. In addition, the spatial coincidence and juxtaposition of values among and within map layers create new mathematical operations, such as effective distance, optimal path routing, visual exposure density and landscape diversity, shape and pattern.

(.5 hour)	**Maps as Data** — **Discrete map objects** vs. **continuous geographic space** — **Grid data types, structures** and **display** — ***Spatial*STEM classes of analytical techniques**
(1 hour)	**Analyzing Spatial Context** *(Spatial Analysis)* — **Basic GridMath & Map Algebra** *(+ - * /)* — **Advanced GridMath** *(Math, Trig, Logical Functions)* — **Map Calculus** *(Spatial Derivative, Spatial Integral)* — **Map Geometry** *(Euclidian Proximity, Narrowness, Effective Proximity)* — **Plane Geometry Connectivity** *(Optimal Path, Optimal Path Density)* — **Solid Geometry Connectivity** *(Viewshed, Visual Exposure)* — **Unique Map Analytics** *(Contiguity, Size/Shape/Integrity, Masking, Profile)*

Spatial Statistics (1.5 hour). *Spatial Statistics* involves quantitative analysis of the “numerical context” of mapped data, such as characterizing the geographic distribution, relative comparisons, map similarity or correlation within and among data layers. Spatial Analysis and Spatial Statistics form a map-*ematics* that uses sequential processing of analytical operators to develop complex map analyses and models. Its approach is similar to traditional statistics except the variables are entire sets of geo-registered mapped data.

(1.5 hour)	**Analyzing Numeric Context** *(Spatial Statistics)* — **Basic Descriptive Statistics** *(Min, Max, Median, Mean, StDev, etc.)* — **Basic Classification** *(Reclassify, Contouring, Normalization)* — **Map Comparison** *(Joint Coincidence, Statistical Tests)* — **Unique Map Statistics** *(Roving Window and Regional Summaries)* — **Surface Modeling** *(Density Analysis, Spatial Interpolation)* — **Advanced Classification** *(Map Similarity, Maximum Likelihood, Clustering)* — **Predictive Statistics** *(Map Correlation/Regression, Data Mining Engines)*

Future Directions (.5 hour). Most GIS technology has deep roots in manual mapping and geo-query procedures involving discrete spatial objects— continuous mapped data promises a future that moves well beyond mapping. The current cycle of innovation is focused on *hexagonal/dodecahedral* grid representation and implementation of a latitude/longitude-based *universal spatial database key* which are poised to change how we conceptualize, visualize, process and analyze spatial data.

Note: short breaks are included between sessions.

Workshop Organization and Logistics

The workshop is not a didactic training course in GIS principles, procedures and software techniques for geospatial specialists. Nor is it a dog-and-pony slideshow/lecture describing GIS applications. Participants will be actively engaged in thought-provoking lecture and discussion on applying spatial reasoning skills and map analysis procedures to their own field of expertise and professional interests.

Background Reading:

- A Math/Stat Framework for Grid-based Map Analysis and Modeling — *Topic 30 in the online book Map Analysis III, a compilation of Beyond Mapping columns in GeoWorld since 1989.*
  http://www.innovativegis.com/basis/MapAnalysis/Topic30/Topic30.htm
- Making a Case for SpatialSTEM: Spatial Considerations in Science, Technology, Engineering and Mathematics Education — *a 15-page white paper describing a framework for grid-based map analysis and modeling concepts and procedures as direct spatial extensions of traditional mathematics and statistics.*
  http://www.innovativegis.com/basis/Papers/Other/SpatialSTEM/SpatialSTEM_case.pdf
- *Spatial*STEM: Extending Traditional Mathematics and Statistics to Grid-based Map Analysis and Modeling — *white paper describing an innovative approach for teaching map analysis and modeling fundamentals within a mathematical/statistical context.*
  http://www.innovativegis.com/basis/Papers/Other/SpatialSTEM/SpatialSTEM_extendedcase.pdf
- Further *Spatial*STEM Readings — *a comprehensive appendix to the SpatialSTEM "extended readings" with URL links to over 125 additional readings on the grid-based map analysis/modeling concepts, terminology, considerations and procedures described in the papers on SpatialSTEM.*
  http://www.innovativegis.com/Basis/Courses/SpatialSTEM/sSTEMreading.pdf
- Math/Stat Classification of Spatial Analysis and Spatial Statistics Operations (MapCalc by Basis) — *white paper listing **MapCalc** operations by traditional mathematics and statistics categories*
  http://www.innovativegis.com/basis/Papers/Other/Esri_Forestry2012/SA_SS_Operations_MapCalc.pdf
- Math/Stat Classification of Spatial Analysis and Spatial Statistics Tools (Spatial Analyst by Esri) — *white paper listing **Spatial Analyst** module operations by traditional mathematics and statistics categories*
  http://www.innovativegis.com/basis/Papers/Other/Esri_Forestry2012/SA_SS_Operations_SpatialAnalyst.pdf
- Beyond Mapping III — *an online book containing Introduction, 28 Chapters and Epilog as a compilation of the popular Beyond Mapping columns published in GeoWorld magazine from 1996 through present, BASIS, Fort Collins, Colorado, 2012. J.K. Berry.*
  http://www.innovativegis.com/basis/MapAnalysis/
- Online Papers — *a listing of numerous online papers discussing Geotechnology issues and Map Analysis/Modeling concepts, procedures and practice. Of particular relevance is an 80-page chapter in the ASPRS Manual of Geographic Information Systems entitled GIS Modeling and Analysis.*
  http://www.innovativegis.com/basis/Papers/Online_Papers.htm
- Royalty Free Teaching Materials — *links to instructional materials to include lecture PowerPoints, readings, exercises and MapCalc software for grid-based map analysis and modeling supporting a variety of teaching environments.*
  http://www.innovativegis.com/basis/Papers/Other/SpatialSTEM/RoyaltyFree_materials_SpatialSTEM.htm
- GIS Modeling Course Materials *by Joseph K. Berry, all of the supporting materials (PowerPoint, Software, Exercises, Exams, Projects) needed for a 10-week graduate level college course (2013).*
  http://www.innovativegis.com/basis/Courses/GMcourse13/

About the Instructor

***Joseph K. Berry** is a leading consultant and educator in the application of Geographic Information Systems (GIS) technology. He is the author of the popular books Beyond Mapping, Spatial Reasoning and Map Analysis, author of the Beyond Mapping column for GeoWorld magazine for over twenty years, and written over two hundred papers on the theory and application of map analysis and modeling techniques. Since 1976, he has presented college courses and professional workshops on geospatial technology to thousands of individuals from a wide variety of disciplines. He holds a B.S. degree in forestry from the University of California, Berkeley, a M.S. in business management and a PhD emphasizing remote sensing and land use planning from Colorado State University.* **http://www.innovativegis.com/basis/basis/cv_berry.htm**