GIS, Spatial Analysis & Spatial Thinking: Essential Tools for the Modern Geoscientist’s Toolbox

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Outline

- My work
  - Mapping & classification
  - Digital terrain analysis
  - Fuzzy logic & classification
  - Hydrologic modeling
  - Spatial analysis
  - Geocomputation
- Interdisciplinary spatial science
- Overlap w/ earth science
- Final comments

Mapping & classification

- USDA Soil Taxonomy
  - Hierarchical classification consisting of soil orders, sub-orders, great soil groups, families & series
  - Lower levels described by soil moisture & temperature regimes as well as characteristic horizons
- Spatial structure
  - Soil map units

Mapping & classification (2)

- Paucity of measurements
- Reliance on proxy variables & crisp logic
- Multiple sources of error & uncertainty
- Scale dependent map products with multiple one-to-many linkages embedded in them

Digital terrain analysis

- Terrain plays key role in modulating atmospheric & earth surface processes
- Digital elevation models play key role
- Calculate first & second derivatives plus variety of primary & secondary topographic attributes

Topographic attributes

Elevation (z)
Slope gradient (G)
Slope aspect (A)
Curvature (K)
Distance to the nearest ridge
Downslope length
Upland area

Slide Courtesy of Bard Romstad
Elevation & slope

Plan & profile curvatures

Upslope contributing areas

Topographic wetness indices

Energy inputs

Net solar radiation
Geomorphometry

- Science of digital terrain analysis
- Rapidly evolving field – LiDAR & related RS technologies
- Focuses on extraction of land surface parameters & land surface objects from digital topography
- Provides valuable model support …

Modeling solum depth

- Regression trees
  - Used five inputs & described 90% of variation
  - Based on 73 observations
- Generalized linear models
  - 3 inputs (TWI, STI, & potassium content)
  - Described 75% of variation

Fuzzy logic & classification

- Two basic approaches
  - Semantic import models
  - Fuzzy k-means
- Fuzzy classification of landscapes
  - Point Dume 1:24K USGS map quadrangle
Fuzzy landform classes
- Coastal plain
- Footslopes
- Stream channels
- North-facing steep slopes
- South-facing steep slopes
- Hilltops / ridgelines

Hydrologic modeling
- Determine quantities of contaminants entering stream network
- Simulate transport of contaminants in reservoirs, rivers & groundwater
- Predict water quality by stream catchment

Study area

MIKE BASIN
- Simple rainfall-runoff & pollution loading model authored by Danish Hydraulic Institute
- Runs on top of ArcGIS toolbox
- Incorporates easy-to-use model calibration & validation tools

WQ module user interface

National Hydrography Dataset
- Stream address system for linking water-related information to national drainage network
- Supports upstream / downstream modeling along drainage network
- Provides rich cartographic feature content for making maps
Drainage enforcement

Model discretization

- Drains 2,200 km²
- 1,783 unique stream segments (links) in NHD Plus
- 171 tributaries and sub-catchments used for MIKE BASIN model runs
- 11.73 km² (1,173 ha) minimum map unit

Rainfall-runoff model analysis

- Key inputs
  - NHD Plus
  - Rainfall, ET & temperature time series
  - Stream flow data for model calibration & validation

Rainfall-runoff model results

Santa Monica Bay flows

Contaminant sources

- Point sources
  - Five major NPDES polluters
- Domestic sources
  - Population data
  - Sewage treatment plants
  - Distance decay calibration factor
- Fertilizer sources
  - Crop data
  - Fertilizer application rates
  - Distance decay calibration factor
- Livestock sources
Spatial analysis

- Melanoma is one of most rapidly increasing cancers among white population in U.S.
- Studies consistently point to UV exposure as most important risk factor
- Individual sun exposure has proved difficult to quantify
- How well can we model spatial variations in UV radiation given measurement network & interpolation techniques available (in 2005)?

Measurement network

Radiation data correlations

Thiessen polygon error map

Springfield – Bondville, IL
Las Vegas – Desert Rock, NV
Boulder – Boulder, CO
Fort Peck – Glasgow, MT
Goldwin Creek – Memphis, TN
Penn State – Williamsport, PA
Sioux Falls – Sioux Falls, SD
Model differences

- Spline predictions 11 & 2.2 times better than Thiessen polygon & kriged predictions
- ANUSPLIN ...
  - Smallest RMSE, MAE & VE
  - Highest R (observed / predicted)
  - Smallest R (observed / error)

ANUSPLIN UV exposure model

- Used Arc/Info GRID tools to calculate zonal means
- Generated map of UV exposures by county

Geocomputation

- Collaborative work w/ JC Chen & Rhonda Spencer, Keck School of Medicine
- National study tracing health of 7,500 women spread across 22 states
- Subjects undergo cognitive function testing annually (40 clinical centers)
- We would need to calculate mean solar light exposures for 0.5, 1, 3, 6 & 12 month intervals preceding each annual test

Interdisciplinary spatial science

- Start w/ Geography Department UCAR review (04/09)
- Spatial Science Faculty Advisory Committee established 08/09
  - College of Letters, Arts & Sciences (4)
  - Keck School of Medicine (2)
  - School of Architecture (1)
  - School of Policy, Planning & Development (2)
  - School of Social Work (1)
  - Viterbi School of Engineering (2)
- Proposal submitted to Provost on 12/09
Motivation

• Systematic development of computational tools for handling spatial data began in 1960s
• Geographic information systems & software for image processing, pattern recognition, & scientific visualization are now in widespread use throughout academy
• Functions for manipulation, analysis, & modeling of spatial data available in standard statistical & mathematical packages
  – ArcGIS, for example, has 750 such functions

Motivation (2)

“The development of relevant theory and concepts, and the cultivating of spatial intelligence through education, has lagged far behind, however, and it is clear that a wide gap exists between the power and accessibility of tools on the one hand and the ability of researchers, students, and the general public to make effective use of them on the other.”

(Geography Department UCAR Committee Report, 2009)

Interdisciplinary Spatial Science B.A.

• Small core (22 units)
  – Fundamentals of design communication
  – Introduction to geographic information systems
  – Principles of geographic information science
  – Principles of remote sensing
  – GIS design & applications
  – Geographic information systems & planning applications
• Plus Computing, Planning & Design, & Quantitative Analysis tracks (12 units)

Interdisciplinary Spatial Science Ph.D.

• Spatial science doctoral certificate program
• Five core courses
  – Fundamentals of spatial thinking
  – Principles of spatial analysis
  – Geospatial information management
  – Geocomputation
  – Current topics in spatial science
• New spatial science doctoral program sponsored by College & Keck School of Medicine?
• NSF IGERT proposal submitted in 03/10

GIST Online Programs

• M.S. & Graduate Certificate programs
• Nine semester courses
  – Concepts for spatial thinking
  – Spatial databases
  – Spatial analysis & modeling
  – Geospatial project management
  – GIS programming & customization
  – GPS/GIS field techniques
  – Remote sensing for GIS
  – Cartography & visualization
  – Web GIS
• Embanet partnership

GIS Research Laboratory

• Designated ESRI Development Center
• Build & support geospatial web services
• Manage campus site licenses & support variety of geospatial software tools
Overlap w/ earth sciences

- The earth sciences cover wide array of challenges facing society in 21st century ranging from energy to environmental concerns
- Students require new types of training & additional skills to address complex interactions between physical, chemical, & biological systems operating across multiple spatial scales
- New spatial science courses can help to provide this training

Final Comments

- Spent my career modeling space-time variability of patterns & processes operating on Earth’s surface
- Our theories, models & observations now immersed in rich new computational settings
- We can all work at finer granularities than we have up to this time

Slide courtesy of Tim Davie