Beyond Mapping in GIS Applications to Environmental Analysis

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NWS Survey on GIS Applications

• A summary by Roger Shriver
• 25 NWS and RFC offices responded
• Arcview 3.x, Arcview 8.x, spatial analyst, and 3D analyst
• Applications
  – Background maps (terrain, administrative boundaries, weather stations, weather radar locations, etc.)
  – Flood or snow mapping
  – Basin delineation
  – Hydrological modeling
  – Internet mapping

Mostly on Mapping
NWS Survey on GIS Applications

- Suggestions on future directions
  - Training
  - Geospatial data access
  - GIS on Linux
  - GIS data support for AWIPS
  - Distributed GIS computing
  - NOAA internet map services

Mostly about Data
GIS: A convergence of...

Mapping
Depth of 100 year flood with roads and buildings

Spatial Analysis
Saving Lives and Responding to Natural Disasters

Database

Internet
Mapping

- Global Positioning Systems
- Remote Sensing
- Cartography
GIS Data

Homes
School Districts
Streets
Zip Codes
Cities
Counties
Spatial Analysis

Network analysis
Spatial Analysis

3D mine with well data
Spatial Analysis

Environmental monitoring of toxic plume

TCE at -80 Feet MSL
Spatial Analysis

Environmental analysis of water quality
Beyond Mapping …

- **GIS Data**
  - Data management and integration
  - Data access and query

- **Analysis**
  - Feature extractions
  - Spatial and temporal relationships
  - Location-based
  - Object-based
Some examples ...

- Analysis of tornado damage
- Geographic analysis of flash flooding
- Weather intelligence
Analysis of Tornado Damage


Tornado damage paths are apparent.

How many tornado damage paths can we identify on this image?

To what extent we can use this image to identify tornado damage paths?

How can we apply what we learned from this image to other high-resolution images, such as CARTERRA images, on tornado-damage identification?
More than just looking...

- **Principle Component Analysis (PCA)** to identify the spectral combination that is best to reveal tornado damage;
- **Normalized Difference Vegetation Index (NDVI)** to identify the quantity and activity level of vegetation;
- **Overlay with tornado damage survey data** to relate signals on the image to damage on the ground.
A clearer look:
the second principle component image
What did we find?

The second principle component image can detect F3 and F4 damage.
NDVI change can detect F1 and F2 damages
Results

- LISS III multispectral image
- PCA: F4 in rural area, F3 in urban area
- NDVI change analysis: F1 or F2
Flash flooding

Evaluating the Effect of Basin Size on the Effectiveness of Flash Flood Guidance: A case study in central Arizona

Part 1 of Master’s thesis by David Slayter (May 2003)
Hypothesis

- $H_0$: There is no difference between the occurrence of flash flooding among 2, 10, and 100 sq mile basins.
- $H_A$: There is a significant difference between the occurrence of flash flooding among 2, 10, and 100 sq mile basins.
Data Sources

- **Flash Flood Events**
  - Forty-nine NCDC-reported flash floods occurring under KIWA or KFSX during summer months (July – early Sept.) in 1998 and 1999.

- **NEXRAD**
  - Archived Level II NEXRAD data from KIWA and KFSX.
  - Digital Hybrid Scan Reflectivity data generated using WATADS version 10.2.

- **Basins**
  - One-arc-second (~ 30-meter) National Elevation Dataset DEMs.
Location of Flash Floods, Flash Flood “Areas”, and WSR-88D Installations
Arizona FFGs and Forecast Areas
Example of 2, 10, and 100 sq mile basins.
Flash flood reported in Washington Park on 7/11/99 15:40 MST
Methodology

- AMBER warnings were compared to reported flash floods to assess the degree of association.
  - There were no 100 mi² basins in this analysis that had a flash flood warning.
- Three flash floods cases defined in this analysis:
  - Case 1: Rainfall >= FFG and FF occurred.
  - Case 2: Rainfall >= FFG and no FF occurred.
  - Case 3: Rainfall < FFG and FF occurred.
  - These cases were analyzed by basin size.
Results

Case 1: Rainfall >= FFG and FF occurred.
Case 2: Rainfall >= FFG and no FF occurred.
Case 3: Rainfall < FFG and FF occurred.

2 sq miles

<table>
<thead>
<tr>
<th></th>
<th>YES</th>
<th>NO</th>
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<tbody>
<tr>
<td>&gt;= FFG</td>
<td>17</td>
<td>626</td>
</tr>
<tr>
<td>&lt; FFG</td>
<td>32</td>
<td></td>
</tr>
</tbody>
</table>

Flood Observed?

POD = Case 1 / (Case 1 + Case 3) = 35%
FAR = Case 2 / (Case 1 + Case 2) = 97%
CSI = Case 1 / (Case 1 + Case 2 + Case 3) = 3%

10 sq miles

<table>
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<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;= FFG</td>
<td>8</td>
<td>112</td>
</tr>
<tr>
<td>&lt; FFG</td>
<td>41</td>
<td></td>
</tr>
</tbody>
</table>

Flood Observed?

POD = 16%
FAR = 93%
CSI = 5%
Conclusions

- Ten and 100 square mile basins are too large to be effectively used for flash flood warnings using current FFGs.
  - POD for 10 sq mile basins of 16%
  - No 100 square mile basins had an accumulation > an FFG.
- Using AMBER and current FFGs, reported flash floods are associated best with basins delineated at the 2 square mile threshold.
Part 2 of Slayter’s thesis

- Physiographic analysis: 2 sq mile basins
- Calculated parameters
  - Mean basin slope
  - Basin relief
  - Basin shape
    - Shape factor
    - Compactness coefficient
  - Mean stream slope
  - STATSGO hydrologic group
  - STATSGO drainage group
  - Basin majority land use type
  - Basin majority land use fragmentation
  - Variety of land use types per basin
Flash Flood Thresh based on logistic regression of physiographic parameters

On CDROM proceedings of 19th International Conference on Interactive Information Processing Systems for Meteorology, Oceanography, and Hydrology, 2003 AMS meeting, Long Beach, CA.
Geographic Intelligence

From spatial and temporal data:
- To look for process signatures and their implications
- To interpret how a geographic process evolves
- To relate processes in space and time

Goal: Build GIS databases with geographic intelligence
Events, Processes, and States

Events, Processes, and States trigger events that drive processes, measured by spatiotemporal data.
Data, States, Processes, and Events
Zones

Levels of Spatiotemporal Aggregation

- Zone
- Sequence
- Process
- Event

Zone A
- T1
- T2
- T3

Zone B
- T4
- T5

Zone C
- T6

Sequence A
- T1
- T2
- T3
- T4
- T5

Sequence B
- T1
- T2
- T3
- T4
- T5

Sequence C
- T1
- T2
- T3
- T4
- T5

Process A
- T1
- T2
- T3
- T4
- T5

Process B
- T1
- T2
- T3
- T4
- T5

Event A
- T1
- T2
- T3
- T4
- T5

Event B
- T1
- T2
- T3
- T4
- T5

4 mm/hr threshold
Sequences

Levels of Spatiotemporal Aggregation

- Zone
  - Sequence
  - Process
  - Event

Zone A

Zone B

Zone C

Sequence A

Sequence B

Sequence C

Process A

Process B

Event A

Event B

T1, T2, T3, T4, T5, T6, T7, T8, T9
Process
Levels of Spatiotemporal Aggregation

- Event
  - Process B
    - Event B
    - Sequence B
      - Zone C
      - Zone A
      - Zone B
  - Process A
    - Event A
    - Sequence A
      - Zone A
  - Process C
    - Event C
    - Sequence C
      - Zone A
  - Process D
    - Event D
    - Sequence D
      - Zone B
  - Process E
    - Event E
    - Sequence E
      - Zone C
Data Structures

Time Series of Gridded Snapshots

Event Table
- EventID
- StartTime
- Duration
- ProcessIDs
- Attributes

Process Table
- ProcessID
- StartTime
- Duration
- Threshold
- SequenceIDs
- Contains
- PartOf
- Attributes

Sequence Table
- SequenceID
- StartTime
- Duration
- Threshold
- ZoneIDs
- Contains
- PartOf
- PreviousSequence
- FutureSequence
- Attributes

Zone Table
- ZoneID
- Time
- Threshold
- RunLengthCode
- Contains
- PartOf
- Attributes

Objects

Fields

Time Series of Gridded Snapshots
Data for Our Case Study

The Arkansas Red River Basin Forecast Center generates hourly radar derived digital precipitation arrays:
- 8760 raster layers per year

Arkansas-Red Basin River Forecast Center Digital Precipitation Array (DPA).

Organized as temporal snapshots and available online
Storm paths and velocity
Interactions with a geographic feature

How long did a storm last and how much rainfall was received in this watershed?

Duration: 4 hours
Cumulative volume: 3,499,857 m³
Find storms occurring at certain time and duration

A query builder dialog to support queries based on the modeled relationships and object attribute values
Find storms with rotations
Similar change from T1 to T2

Cases from a cluster determined by the six indices we developed to describe both static and dynamic characteristics of storms
Find matching storms ...

Query

Return:
storm systems with similar behaviors
Categorize processes

 hora 1
 hora 2
 hora 3
 hora 4
 hora 5
Hierarchical Clustering
Concluding Remarks

• GIS is more than mapping.
• An information system for spatial data handling, analysis, and visualization.
• How to make sense of spatial and spatiotemporal data?
• How to identify spatial and temporal relationships or associations?
THANK YOU

Questions, Comments?
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