Working with Temporal Data in ArcGIS

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Outline

• Overview of Spatiotemporal data
• Storage and management of temporal data
  – Feature
  – Raster
  – Array (netCDF)
• Visualization of temporal data
• Analysis of temporal data
GIS Integration of Time

New Ways to Manage, Visualize & Analyze Geography

- Extended Data Model
- Tools for Manipulation
  - Query
  - Visualization
    - Animation
    - Charting
  - Iterative Processing
  - Tracking Analysis
  - nDim Forecast Models
  - Change Analysis

Visualize Change

- Multi Dimensional Data (netCDF)
- Files
- DBMS
- Simulation Modeling
- Real Time Sensor Network

Mobile
Stationary
**Time is special**

- Linear, cyclical, uni-directional

- It’s not metric or base 10 so it’s messy
  - A Year is 365, or sometimes 366 days
  - A Month can be 28 days to 31 days
  - Don’t forget time offsets from Greenwich

- Can be stored as Integer, Double, String, or Date

- **DATE** is a special field type specific to time
  - Specific code for that type make it easier to use and faster
  - Not all database support the same type and operators
  - *Use DATE fields whenever possible for your temporal data*
Temporal

*Time, Dates, Spatial-temporal, History*

- First problem – the meaning is overloaded
- Each of us have our own definition and requirements
- Implementations may be unique, but all of them have many similarities...
  - How to model
  - How to store
  - How to access
  - How to optimize
  - How to analyze
What does ArcGIS offer

• **Point-in-time**
  – Simply a **DATE** attribute
  – Metadata
  – Can be leveraged by many geoprocessing tools

• **Duration of time**
  – An interval
  – Multiple attributes (start date – end date)

• **Transactional**
  – Versioning
    • Multiple representations of the data for historical views or what-if-scenarios
  – Archiving
    • System maintained for tracking individual objects changing through time
Accessing temporal data

• How to construct the correct query…

• Point-in-time
  – WHERE event = ‘12-4-2006’

• Duration
  – WHERE start_time >= ‘JAN-1-2005’
    AND end_time <= ‘DEC-31-2005’

• Transactional
  – WHERE audit_date BETWEEN (’11:15:00’ and ’11:45’)

• Valid
  – WHERE since_date = ‘MAY 12, 2007’
Temporal storage models and DBMS options

- **When to use just one table**
  - Data access typically to one table is highly efficient
  - Consequences of storing redundant attributes
    - Same location, but different values for the moment being recorded
    - Can generate millions of entries

- **When to use a layer and a second attribute table for joining**
  - Data access might be impacted by the join operation
  - Provides better data access for the feature class, no redundant storage of geometries

- **Optimize data access by indexing, table partitioning**
  - All JAN recordings in partition 1
  - All FEB recordings in partition 2
  - All MAR recordings in partition 3…
Temporal Raster Data Storage

**Raster catalogs**
- Use a date/time field
- Use an index field (i.e. ObjectID)

**Note:** The layer will initially draw as a wire frame if more than 9 rasters.

<table>
<thead>
<tr>
<th>OBJECTID*</th>
<th>NAME</th>
<th>Shape*</th>
<th>Raster</th>
<th>Date_Time</th>
<th>SHAPE_Length</th>
<th>SHAPE_Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>image1.gif</td>
<td>Polygon</td>
<td>Raster</td>
<td>1998-10-14 12:00:00</td>
<td>3068</td>
<td>522753</td>
</tr>
<tr>
<td>2</td>
<td>image2.gif</td>
<td>Polygon</td>
<td>Raster</td>
<td>1998-10-15</td>
<td>3068</td>
<td>522753</td>
</tr>
<tr>
<td>3</td>
<td>image3.gif</td>
<td>Polygon</td>
<td>Raster</td>
<td>1998-10-15 12:00:00</td>
<td>3068</td>
<td>522753</td>
</tr>
<tr>
<td>4</td>
<td>image4.gif</td>
<td>Polygon</td>
<td>Raster</td>
<td>1998-10-16</td>
<td>3068</td>
<td>522753</td>
</tr>
<tr>
<td>5</td>
<td>image5.gif</td>
<td>Polygon</td>
<td>Raster</td>
<td>1998-10-16 12:00:00</td>
<td>3068</td>
<td>522753</td>
</tr>
<tr>
<td>6</td>
<td>image6.gif</td>
<td>Polygon</td>
<td>Raster</td>
<td>1998-10-17</td>
<td>3068</td>
<td>522753</td>
</tr>
<tr>
<td>7</td>
<td>image7.gif</td>
<td>Polygon</td>
<td>Raster</td>
<td>1998-10-17 12:00:00</td>
<td>3068</td>
<td>522753</td>
</tr>
</tbody>
</table>
Demo
Temporal/Multidimensional Data

Adding a 4th dimension

Altitude

X

Y

Time

141 241 341 441
131 231 331 431
121 221 321 421
111 211 311 411

142 242 342 442
132 232 332 432
122 222 322 422
112 212 312 412

143 243 343 443
133 233 333 433
123 223 323 423
113 213 313 413
Temporal Array Data in ArcGIS

- ArcGIS 9.2 reads writes netCDF
- An array based data structure for storing multidimensional data.
- N-dimensional coordinates systems
  - X, Y, Z, time, and other dimensions
- Variables support for multiple variables
  - Temperature, humidity, pressure, salinity, etc
- Geometry implicit or explicit
  - Regular grid (implicit)
  - Irregular grid
  - Points
Storing Data in a netCDF File

```plaintext
netcdf mynetcdf{
  dimensions:
    X=4;
    Y=4;
    Time=UNLIMITED;
  variables:
    float X(X);
    float Y(Y);
    int Time(Time);
    float Temperature(Time, Y, X);
  data:
    X = 10, 20, 30, 40;
    Y = 110, 120, 130, 140;
    Time = 31, 59, 90;
}
```
Storing Data in a netCDF File

```
netcdf mynetcdf {
    dimensions:
        X = 4;
        Y = 5;
        Time = UNLIMITED;
    variables:
        float X(X);
        float Y(Y);
        int Time(Time);
        float Temperature(Time, Y, X);
    data:
        X = 10, 20, 30, 40;
        Y = 110, 120, 130, 140;
        Time = 31, 59, 90;
        Temperature = 111, 211, 311, 411;
}
```
Storing Data in a netCDF File

```netcdf mynetcdf{
  dimensions:
    X=4;
    Y=5;
    Time=UNLIMITED;
  variables:
    float X(X);
    float Y(Y);
    int Time(Time);
    float Temperature(Time, Y, X);
  data:
    X = 10, 20, 30, 40;
    Y = 110, 120, 130, 140;
    Time = 31, 59, 90;
    Temperature =
      111,211,311,411,121,221,321,421,
      131,231,331,431,141,241,341,441;
}
Storing Data in a netCDF File

```plaintext
netcdf mynetcdf{
    dimensions:
        X=4;
        Y=5;
        Time=UNLIMITED;
    variables:
        float X(X);
        float Y(Y);
        int Time(Time);
        float Temperature(Time, Y, X);
    data:
        X = 10, 20, 30, 40;
        Y = 110, 120, 130, 140;
        Time = 31, 59, 90;

        Temperature =
        111,211,311,411,121,221,321,421,
        131,231,331,431,141,241,341,441,
        112,212,312,412,122,222,322,422,
        132,232,332,432,142,242,342,442,
        113,213,313,413,123,223,323,423,
        133,233,333,433,143,243,343,443;
}
```
NetCDF and Coordinate Systems

• Geographic Coordinate Systems (GCS)
  • X dimension units: degrees_east
  • Y dimension units: degrees_north

• Projected Coordinate Systems (PCS)
  • X dimension standard_name: projection_x_coordinate
  • Y dimension standard_name: projection_y_coordinate
  • Variable has a grid_mapping attribute.
  • CF conventions currently supports only eight predefined coordinate systems

• Undefined
  • If not GCS or PCS
  • ArcGIS writes (and recognizes) PE String as a variable attribute.
NetCDF in ArcGIS

- NetCDF data is accessed as
  - Raster
  - Feature
  - Table

- 7 NetCDF tools
- Direct read
- Exports GIS data to netCDF
Using NetCDF Data

Behaves the same as any layer or table

• Display
  • Same display tools for raster and feature layers will work on netCDF raster and netCDF feature layers.

• Graphing
  • Driven by the table just like any other chart.

• Animation
  • Multidimensional data can be animated through a dimension (e.g. time, pressure, elevation)

• Analysis Tools
  • A netCDF layer or table will work just like any other raster layer, feature layer, or table. (e.g. create buffers around netCDF points, reproject rasters, query tables, etc.)
Temporal Visualization

• The most effective way to convey changes over time and space is through temporal animation.
  
  – Temporal Animation in ArcGIS core

  – Temporal Animation with the Tracking Analyst extension
ArcGIS 9.2 Temporal Animation

- Sequence display of one or more layers on the same time step or index
  - ArcMap, ArcScene, and ArcGlobe
  - Layers and Graphs

- Supported data
  - Feature Layers
  - Raster Catalog Layers
  - netCDF Layers
  - Tables
  - Historical archive layers
  - Tracking Analyst layers
Animation examples

Sea ice concentration


Solar Insolation

Stream flow analysis

Data provided courtesy of Declan Butler - http://declanbutler.info/blog/
Where is temporal animation in ArcGIS?

- Animation toolbar
  - ArcMap, ArcScene, ArcGlobe

- Very simple single panel interface to create a temporal animation
  - Only 2 required inputs
  - Layer you want to animate
  - The field containing the time

No 3D Analyst license is required to animate in ArcMap
Animation is based upon *records* in a Table

- With one table, features repeat for each time stamp
- Each time stamp has an attribute value

E.g. 5 features, 3 time steps
Animating with Joined Tables

- With two tables, if your table relationship is:
  - One-to-many
  - One-to-one
  - Many-to-one

**One-to-many**

- **Stations feature class**
  - OBJECTID: 1, 2, 3, 4, 5
  - SHAPE: Point
  - STATIONID: 43, 55, 21, 15, 30

- **Temperature table**
  - OBJECTID: 1, 2, 3, 4, 5
  - StationID: 43, 43, 43, 43, 43
  - Temp: 50, 53, 49, 58, 55

**Many-to-one**

- **Temperature table**
  - OBJECTID: 1, 2, 3
  - StationID: 43, 43, 43
  - date_1: 1/1/2000, 1/1/2001, 1/1/2002
  - Temp: 65, 70, 72

- **Stations feature class**
  - OBJECTID: 1585, 1673, 1696, 1716, 1720, 1758, 1617, 1590, 1667, 1676, 1727, 1757, 1651
  - SHAPE: Polygon
  - AREA: 11945.5, 4991.00, 2570.2, 42708, 7177.38, 6506.21, 3568.12, 6917.75, 2201.92, 5965.46, 31541.1, 2899.82, 2174.22
  - PERIMETER: 8817588, 8817588, 8817588, 8817588, 8817588, 8817588, 8817588, 8817588, 8817588, 8817588, 8817588, 8817588

Run the Make Query Table tool to perform an in-memory join.
Animating data in graphs

- Create a graph using a layer or table
- Create an animation in the usual way, attaching the layer or table to a time layer track
- When the animation is played, the graph will animate
Tracking Analyst Extension

- ArcGIS Desktop Extension
- Historical and Real-Time Display
- Track Symbology
- Animation Tool
- Playback Manager with temporal event histogram
- Actions
- Temporal Offset
- Data Clock
Using Actions with Tracking Analyst

• Layer Actions
  – Highlight
  – Suppress
  – Run a VB script (real-time only)

• Service Actions (ArcCatalog)
  – Filter the event from further action processing (ArcMap)
  – Filter events you receive from Tracking Server
  – Run a VB script (real-time only)

• Rules check for
  – Some attribute in the data tables
  – Location of the event in relationship to polygon
  – Both
Arc Logistics in 9.3

- Built using
  - ArcEngine 9.3
  - Network Dataset
  - Vrp solver – also in Network Analyst 9.3

Desktop Fleet Routing Application
- Imports Orders
- Geocode Stops
- Optimize Routes
- Provides Manifests, Maps, Directions, Reports
- Exports Routes if required to other applications
Temporal Analysis

• Conflict detection in Tracking Analyst
• Custom processing tasks in Tracking Server

• Temporal Modeling
Demo