



# Working with Temporal Data in ArcGIS

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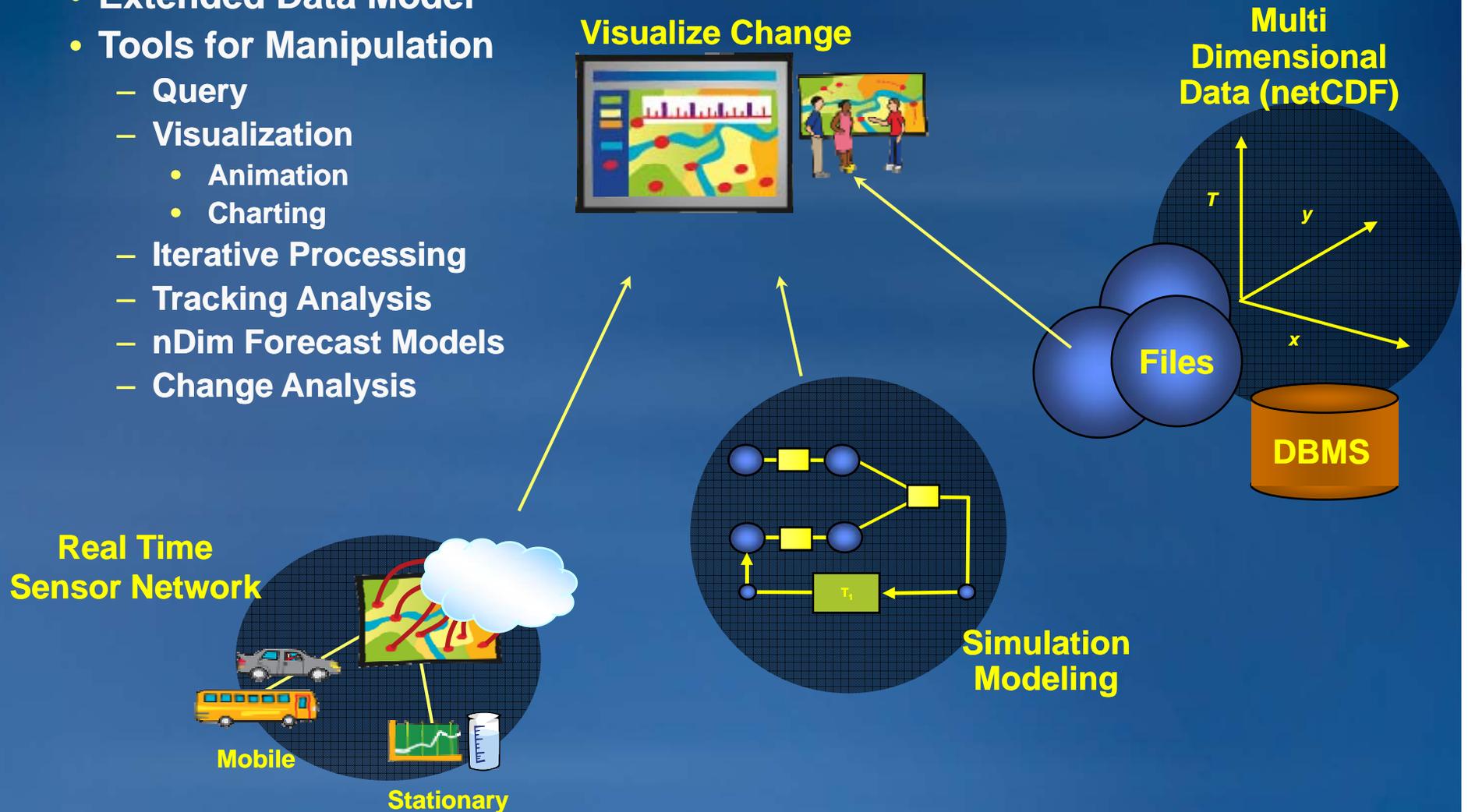
# Outline

- **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



# Time is special

- Linear, cyclical, uni-directional
- Its not metric or base 10 so its 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)

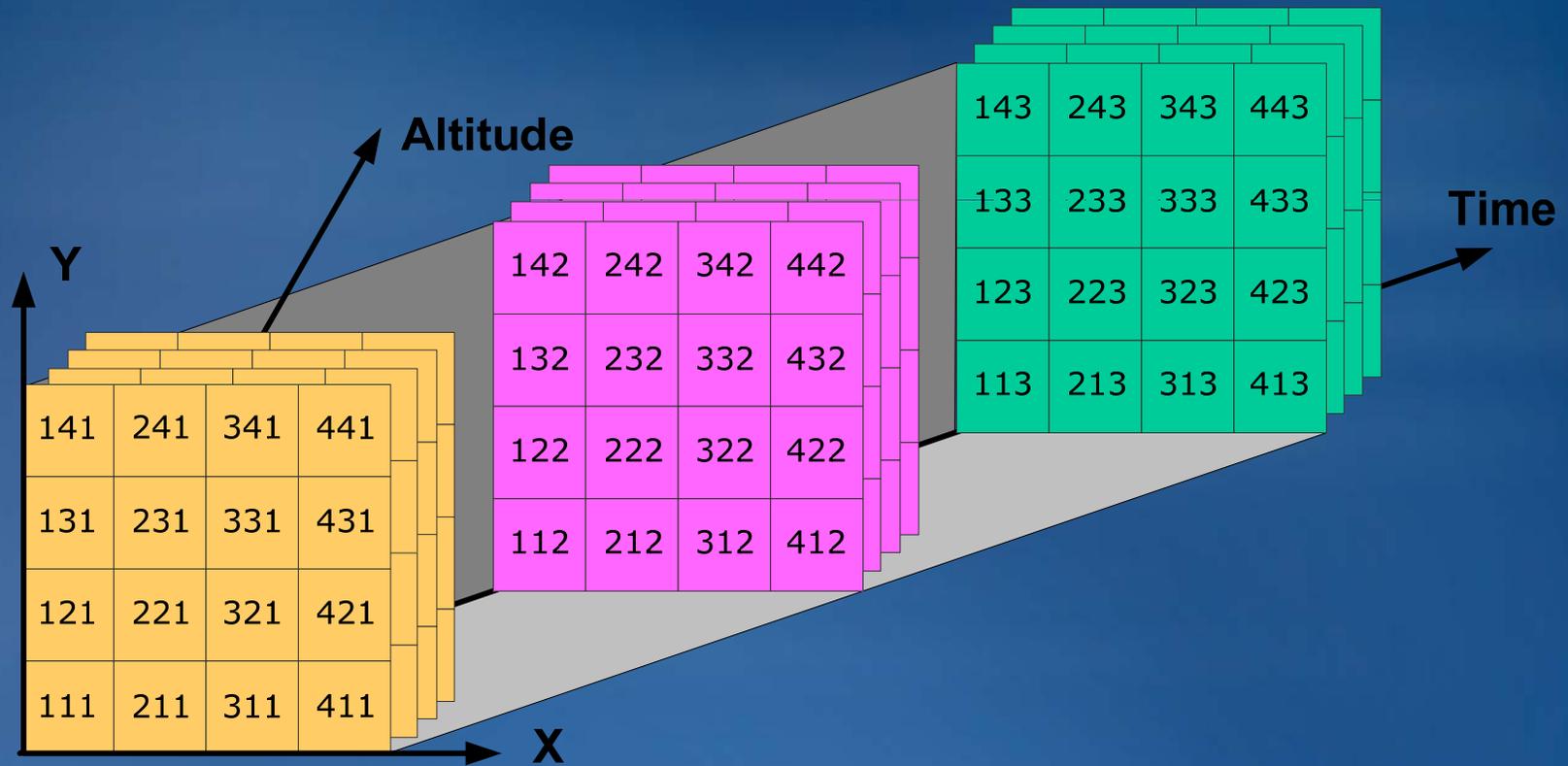
**Note: The layer will initially draw as a wire frame if more than 9 rasters.**

OBJECTID <sup>^</sup>	NAME	Shape <sup>^</sup>	Raster	Date_Time	SHAPE_Length	SHAPE_Area
1	Image1.gif	Polygon	Raster	1998-10-14 12:00:00	3068	522753
2	Image2.gif	Polygon	Raster	1998-10-15	3068	522753
3	Image3.gif	Polygon	Raster	1998-10-15 12:00:00	3068	522753
4	Image4.gif	Polygon	Raster	1998-10-16	3068	522753
5	Image5.gif	Polygon	Raster	1998-10-16 12:00:00	3068	522753
6	Image6.gif	Polygon	Raster	1998-10-17	3068	522753
7	Image7.gif	Polygon	Raster	1998-10-17 12:00:00	3068	522753

**Demo**

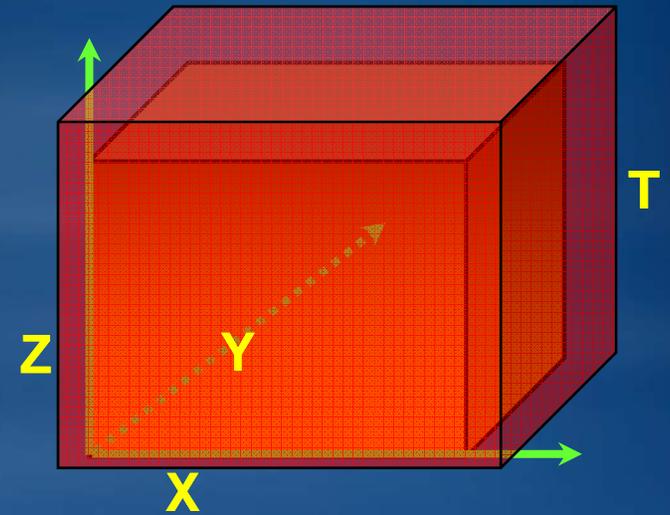
# Temporal/Multidimensional Data

## Adding a 4<sup>th</sup> dimension



# 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

```
netcdf mynetcdf{
```

```
dimensions:
```

```
  X=4;
```

```
  Y=4;
```

```
  Time=UNLIMITED;
```

```
variables:
```

```
  float X(X);
```

```
  float Y(Y);
```

```
  int Time(Time);
```

```
  float Temperature(Time, Y, X);
```

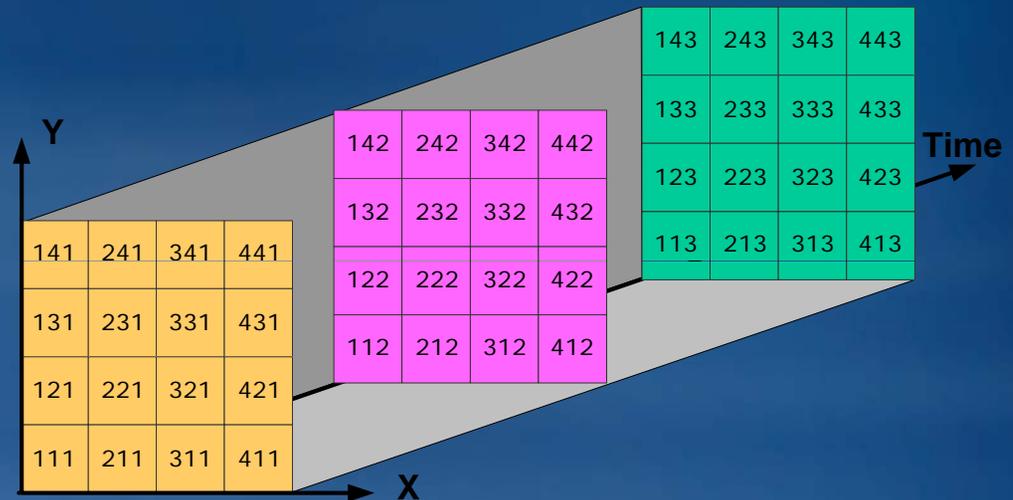
```
data:
```

```
  X = 10, 20, 30, 40;
```

```
  Y = 110, 120, 130, 140;
```

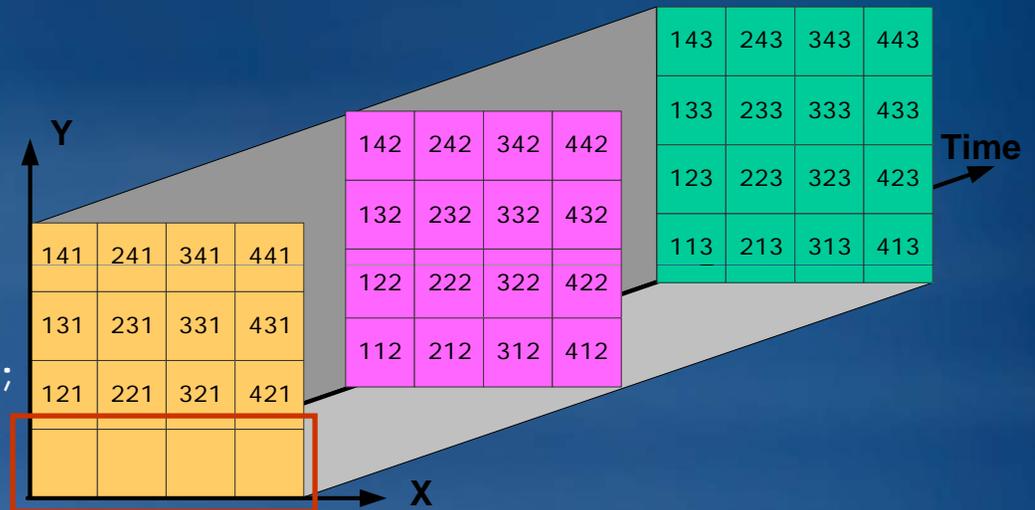
```
  Time = 31, 59, 90;
```

```
}
```



# 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;  
}
```



Time = 1  
Y = 1  
X = 1 to 4

# 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;
```

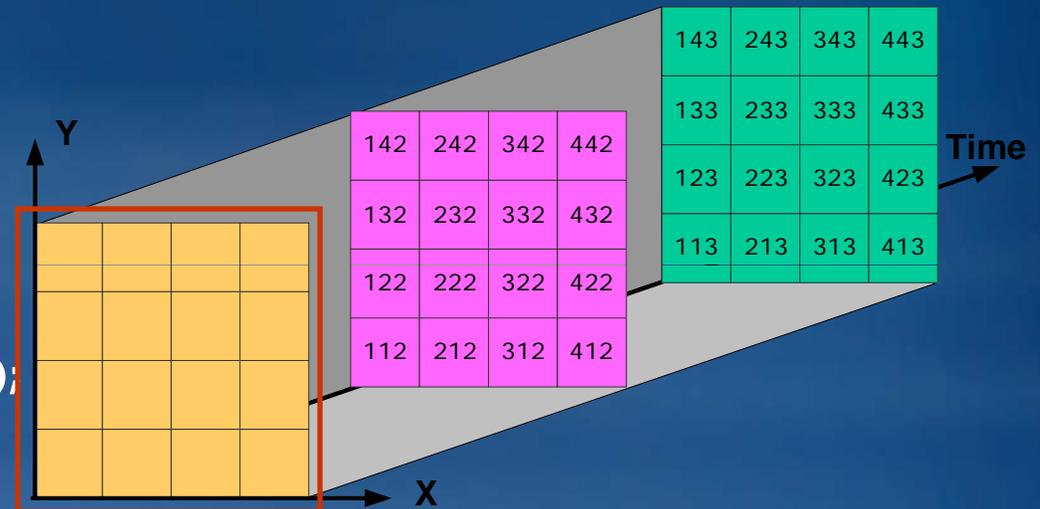
```
  Time = 31, 59, 90;
```

```
Temperature =
```

```
111,211,311,411,121,221,321,421,
```

```
131,231,331,431,141,241,341,441;
```

```
}
```



Time = 1

Y = 1 to 4

X = 1 to 4

# 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,
```

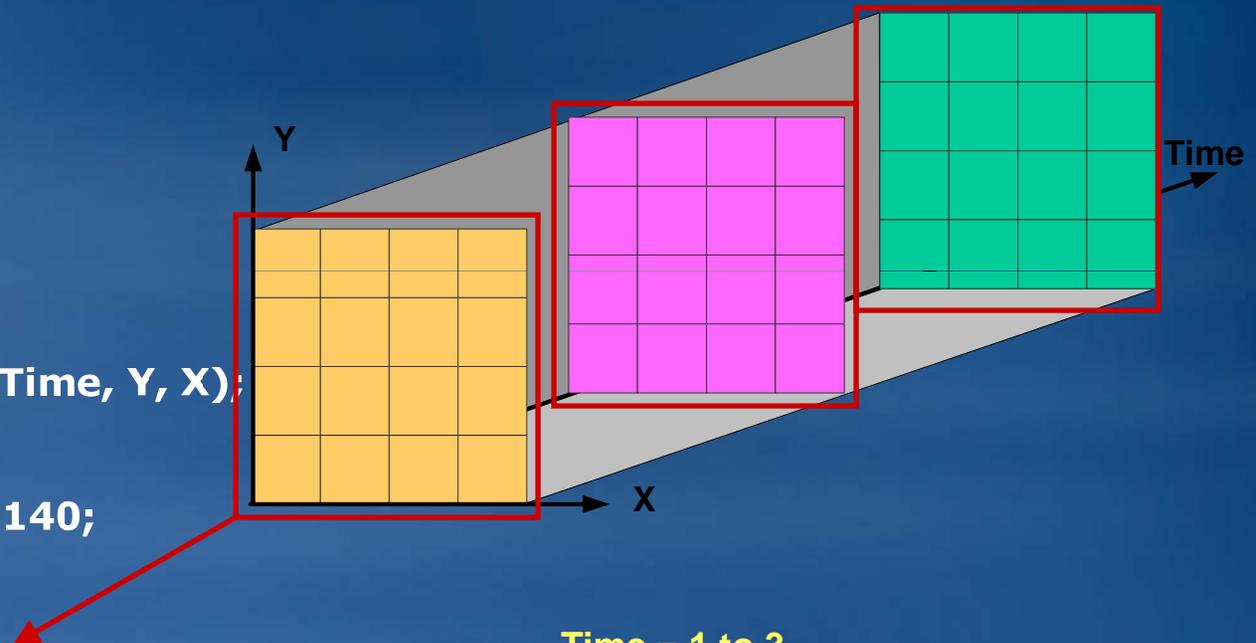
```
  112,212,312,412,122,222,322,422,
```

```
  132,232,332,432,142,242,342,442,
```

```
  113,213,313,413,123,223,323,423,
```

```
  133,233,333,433,143,243,343,443;
```

```
}
```



Time = 1 to 3

Y = 1 to 4

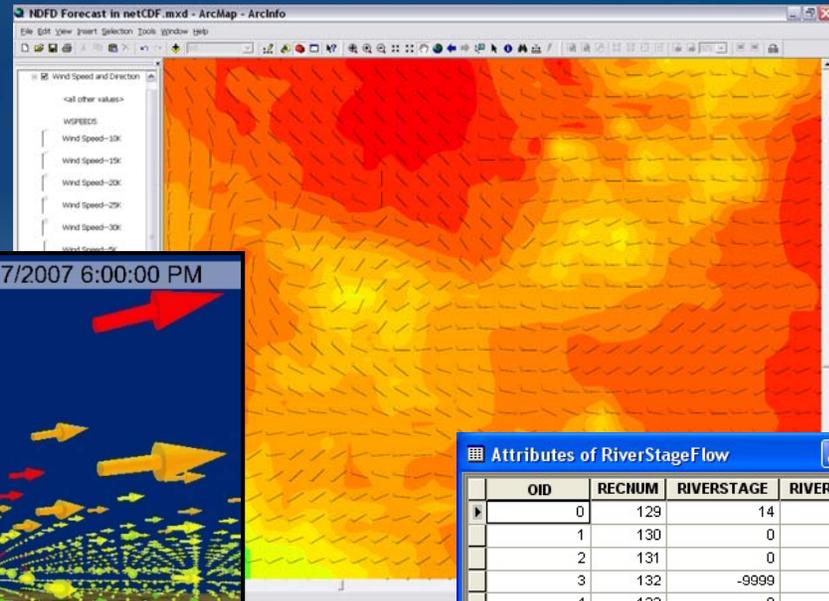
X = 1 to 4

# 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



OID	RECNUM	RIVERSTAGE	RIVERFLOW
0	129	14	0
1	130	0	0
2	131	0	0
3	132	-9999	-9999
4	133	0	0
5	134	0	0
6	135	-9999	-9999
7	136	0	1
8	137	-9999	-9999
9	138	15	0
10	139	-9999	-9999
11	140	-9999	-9999
12	141	7	2
13	142	3	0
14	143	16	1
15	144	-9999	-9999
16	145	-9999	-9999
17	146	-9999	-9999

ArcToolbox

- Multidimension Tools
  - Feature to NetCDF
  - Make NetCDF Feature Layer
  - Make NetCDF Raster Layer
  - Make NetCDF Table View
  - Raster to NetCDF
  - Select by Dimension
  - Table to NetCDF

Buttons: Favorites, Index, Search

# Using NetCDF Data

## Behaves the same as any layer or table

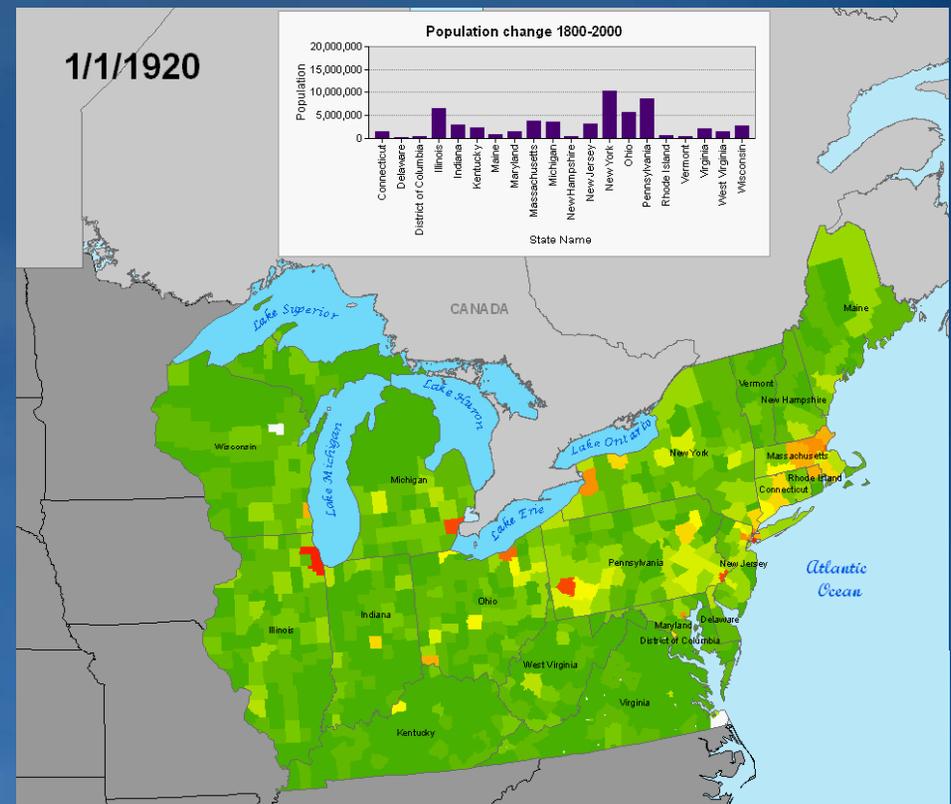
- **Display**
  - Same display tools for raster and feature layers will work on netCDF raster and netCDF feature layers.
- **Graphing**
  - Driven by the table just like any other chart.
- **Animation**
  - Multidimensional data can be animated through a dimension (e.g. time, pressure, elevation)
- **Analysis 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

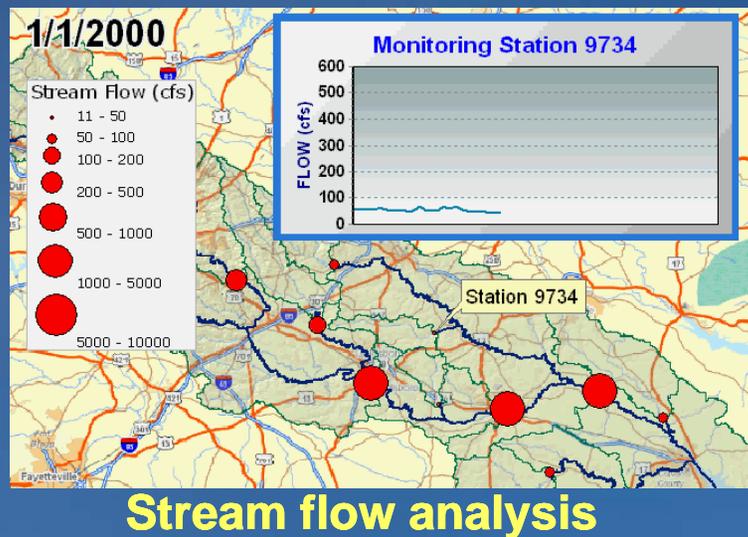
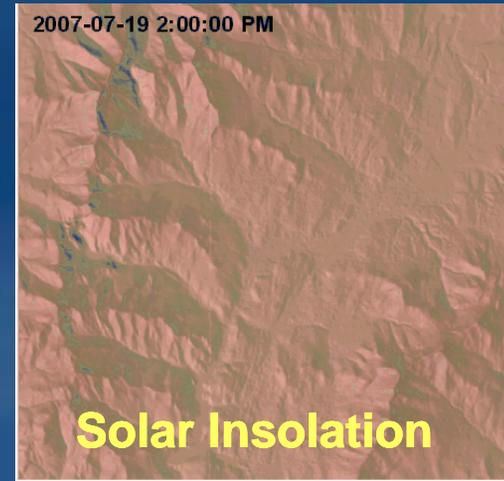
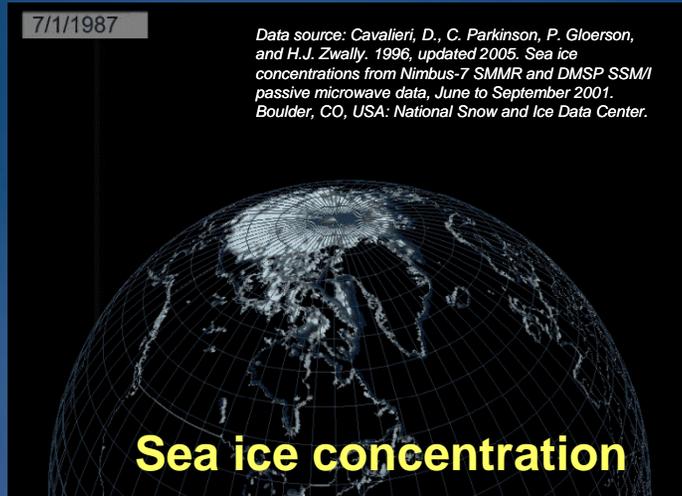
- **The most effective way to convey changes over time and space is through temporal animation.**
  - **Temporal Animation in ArcGIS core**
  - **Temporal Animation with the Tracking Analyst extension**

# 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



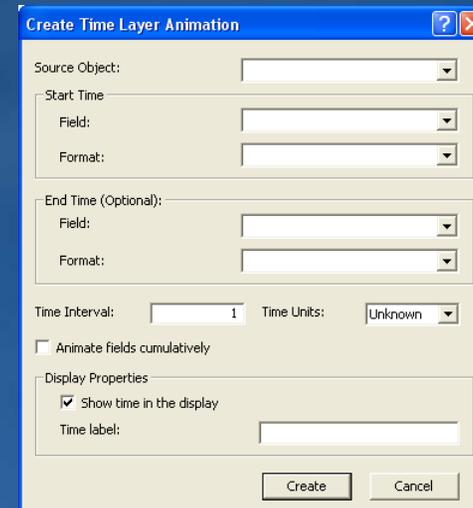
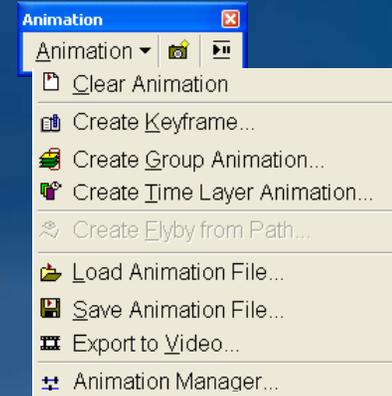
Data provided courtesy of Declan Butler - <http://declanbutler.info/blog/>



# 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

FID	Shape *	FeatureID	TSValue	TSDateTime
0	Point	9679	33	12/1/1999
1	Point	9679	29	12/2/1999
2	Point	9679	26	12/3/1999
3	Point	9680	66	12/1/1999
4	Point	9680	58	12/2/1999
5	Point	9680	54	12/3/1999
6	Point	9685	71	12/1/1999
7	Point	9685	63	12/2/1999
8	Point	9685	58	12/3/1999
9	Point	9694	184	12/1/1999
10	Point	9694	183	12/2/1999
11	Point	9694	183	12/3/1999
12	Point	9705	56	12/1/1999
13	Point	9705	51	12/2/1999
14	Point	9705	47	12/3/1999

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*	SHAPE*	StationID
1	Point	43
2	Point	55
3	Point	21
4	Point	15
5	Point	30

Temperature table				
OBJECTID*	StationID	Date_1	Temp	
1	43	1/1/2000	50	
2	43	1/1/2001	53	
3	43	1/1/2002	49	
4	43	1/1/2003	58	
5	43	1/1/2004	55	
6	55	1/1/2000	65	
7	55	1/1/2001	70	
8	55	1/1/2002	72	
9	55	1/1/2003	69	
10	55	1/1/2004	75	
11	21	1/1/2000	40	
12	21	1/1/2001	45	

## Many-to-one

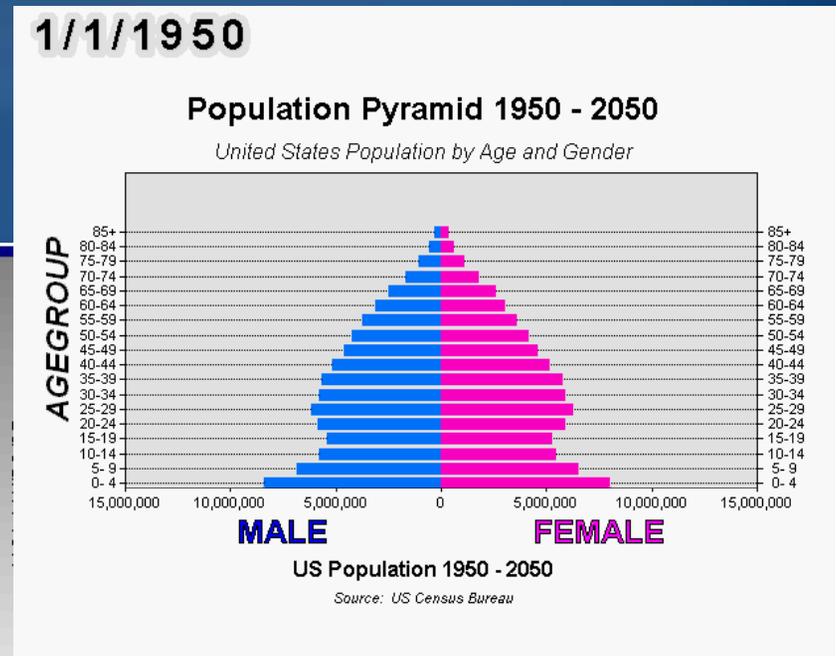
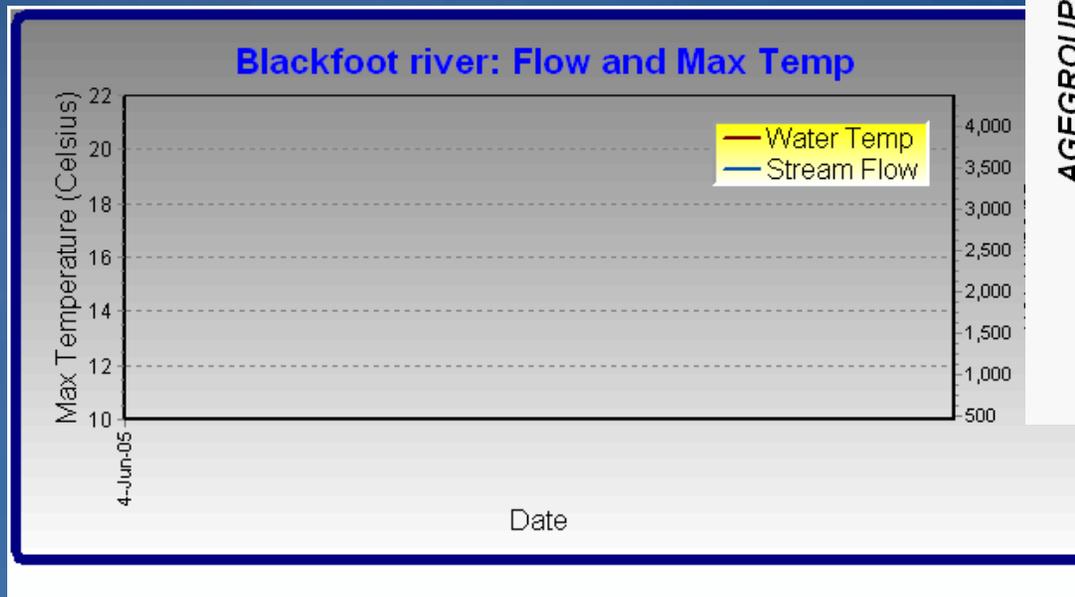
FID	Shape *	AREA	PERIMETER	Date_	ID_
1585	Polygon	2954870	11945.6	8/6/1988	1
1673	Polygon	926243	4991.03	0/6/1900	1
1696	Polygon	123337	2570.8	8/6/1988	1
1716	Polygon	420788	3659.89	8/6/1988	1
1720	Polygon	1716590	7127.38	8/6/1988	1
1758	Polygon	850621	4802.35	8/6/1988	1
1817	Polygon	303861	2535.12	8/6/1988	1
1590	Polygon	573254	6817.78	8/8/1988	1
1667	Polygon	202705	2201.92	8/8/1988	1
1676	Polygon	491833	5369.46	8/8/1988	1
1727	Polygon	12049700	31541.1	8/8/1988	1
1757	Polygon	311894	2899.82	8/8/1988	1
1951	Polygon	234916	2174.22	8/16/1988	2
3	Polygon	17246200	33480	8/19/1988	3
7	Polygon	227399	1972.64	8/19/1988	3

OID	ID_	FIRE
0	1	Shoshone
1	2	Snake
2	3	Storm Creek

**Run the Make Query Table tool to perform an in-memory join**

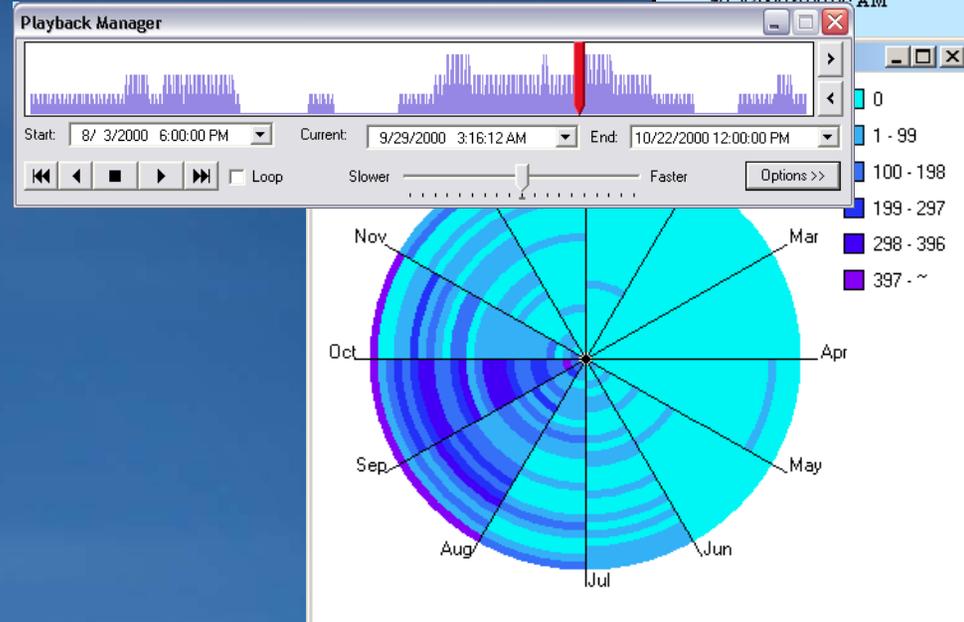
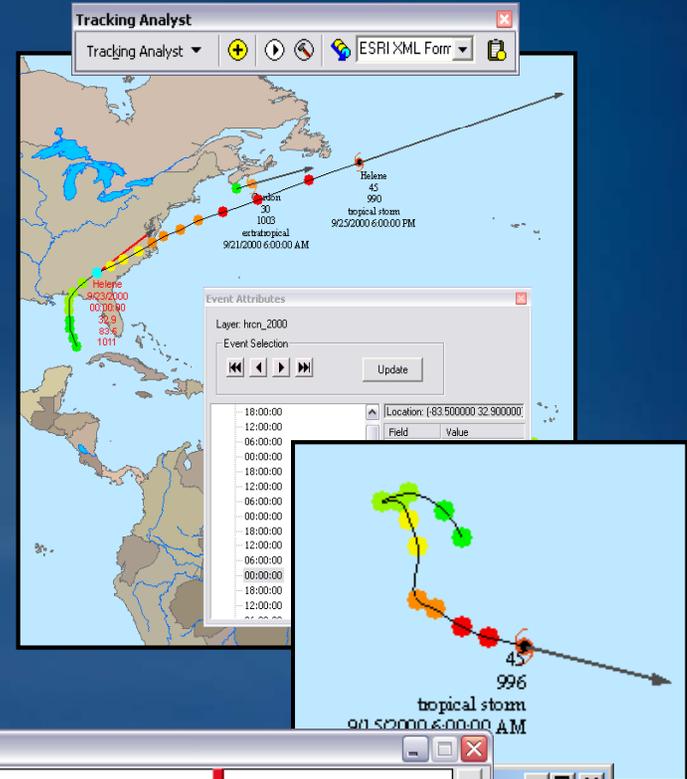
# Animating data in graphs

- 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



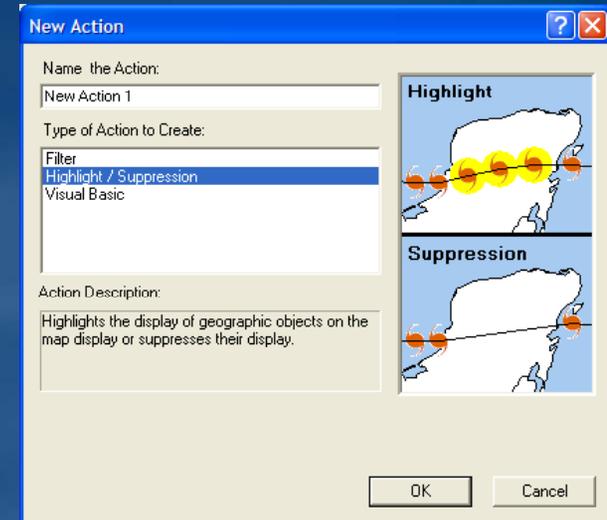
# Tracking Analyst Extension

- 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

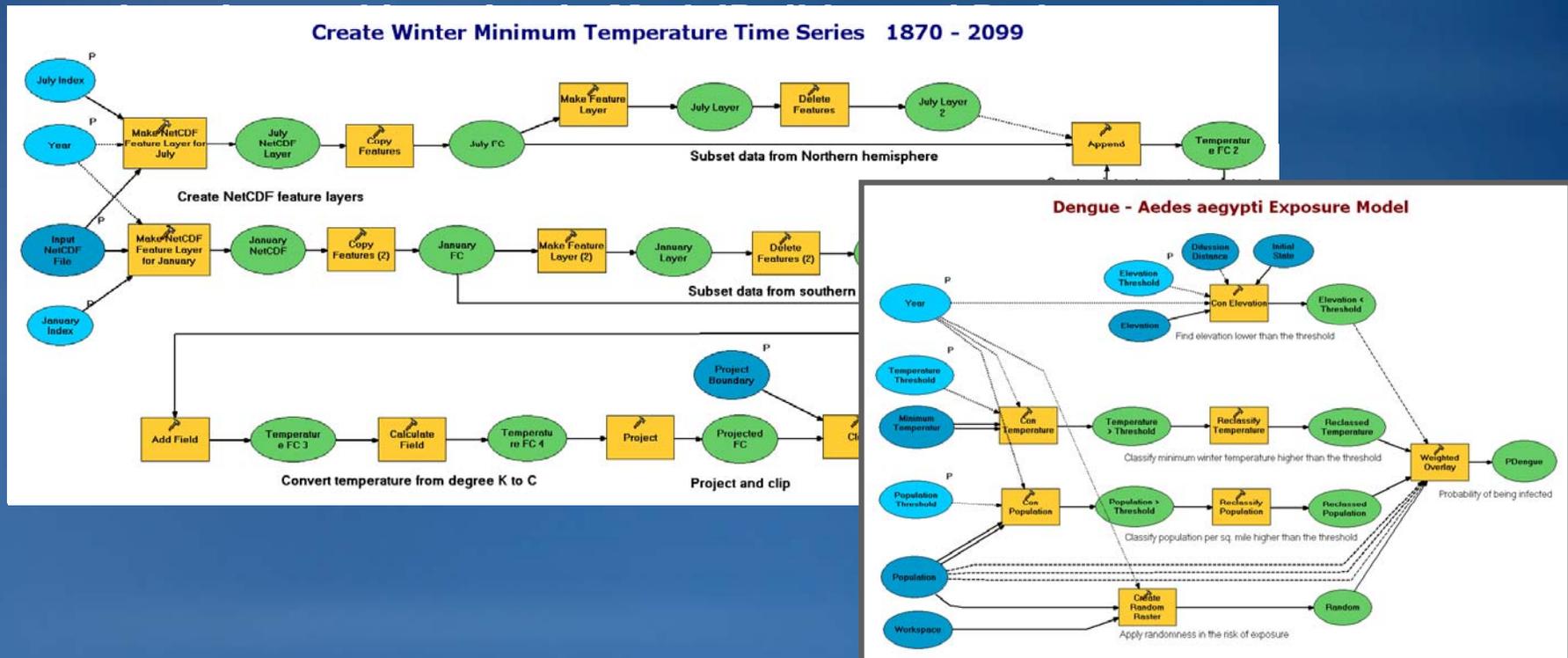
- Built using
  - ArcEngine 9.3
  - Network Dataset
  - Vrp solver – also in Network Analyst 9.3

### 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**

**Questions?**