



**Esri International User Conference | San Diego, CA**  
**Technical Workshops | July 2011**

## **NetCDF Data in Weather and Climate Applications**

Nawajish Noman

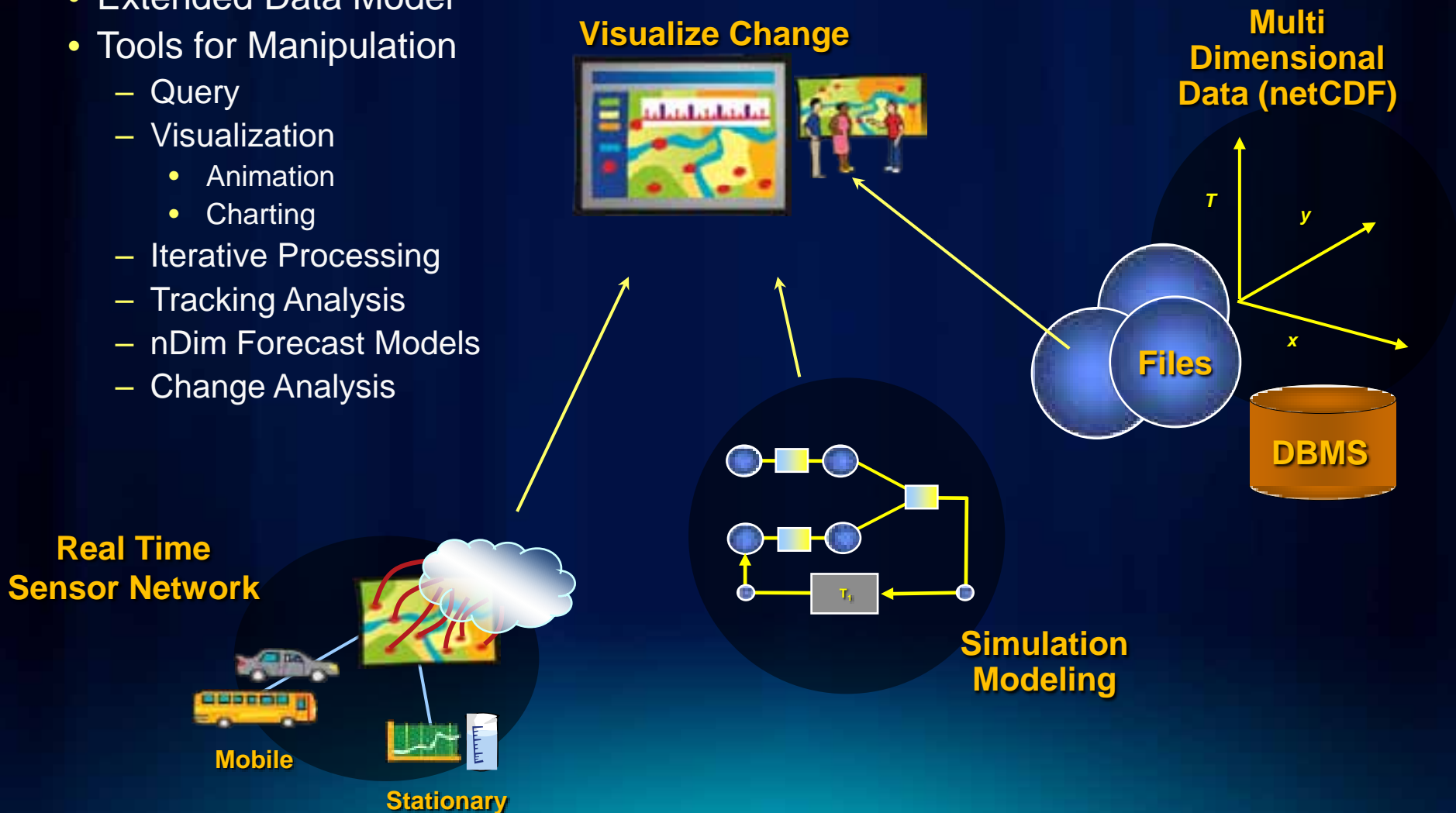
# Outline

- Multidimensional data
- netCDF
- netCDF in ArcGIS
- Working with netCDF
- Help on netCDF

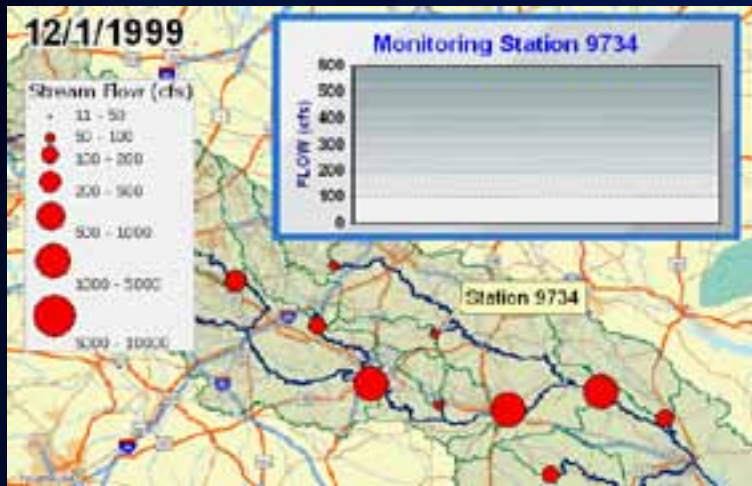
# GIS Integration of Time

## *New Ways to Manage, Visualize & Analyze Geography*

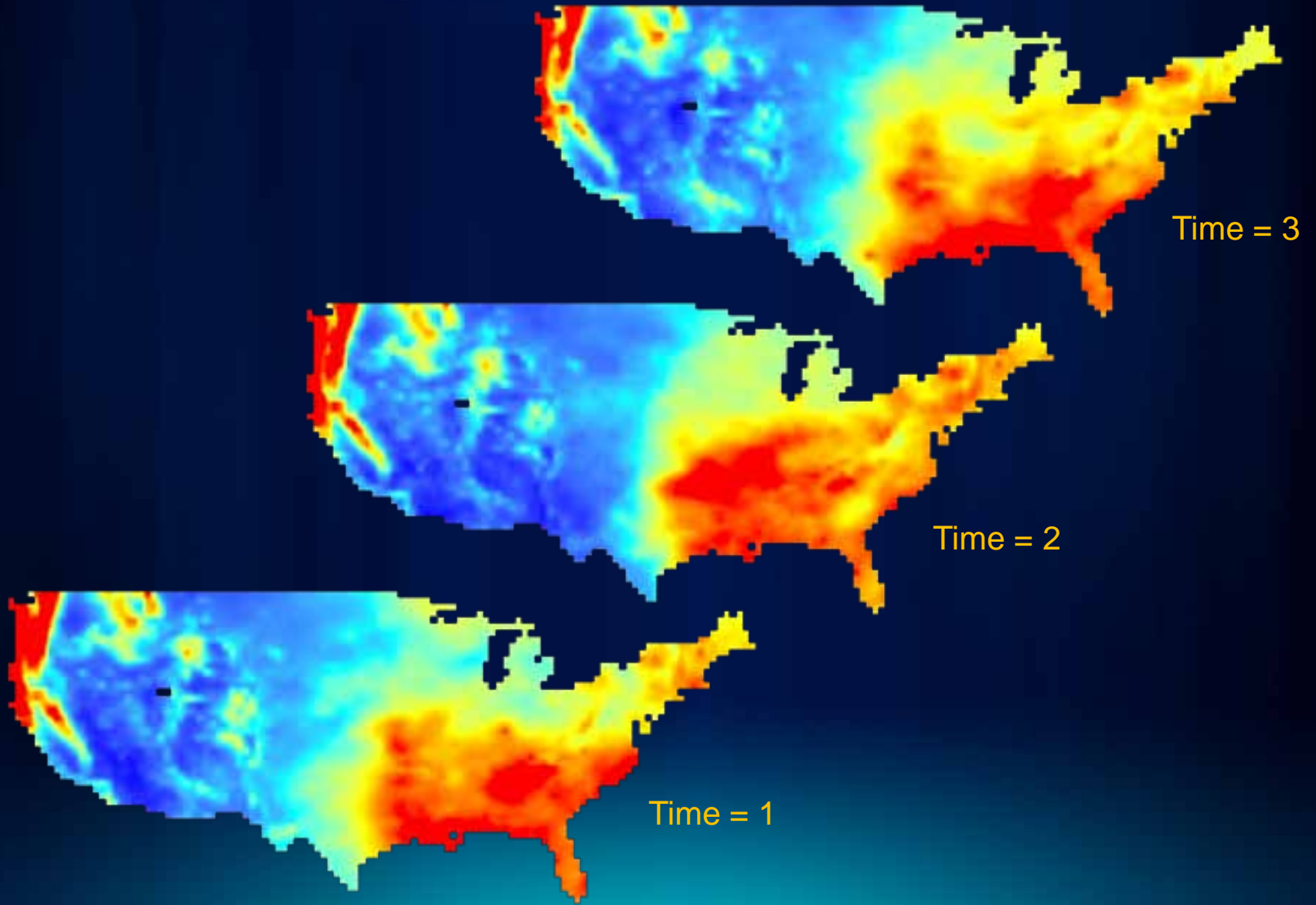
- Extended Data Model
- Tools for Manipulation
  - Query
  - Visualization
    - Animation
    - Charting
  - Iterative Processing
  - Tracking Analysis
  - nDim Forecast Models
  - Change Analysis



# Multidimensional Data



# Multidimensional Data



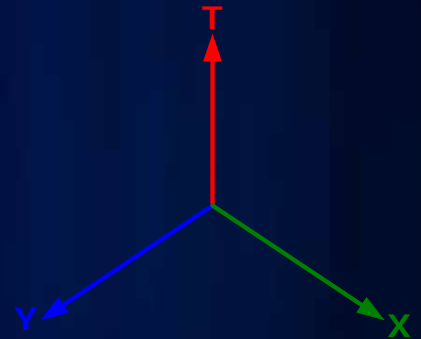
# Multidimensional Data



# Multidimensional Data

*Data cube (3D) or hypercube (4D,5D...)*

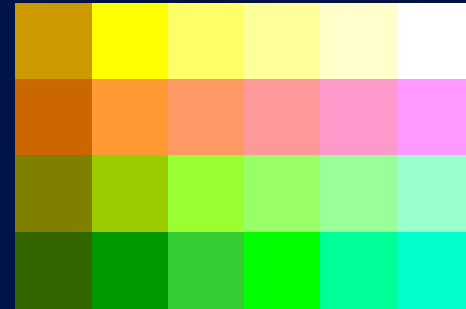
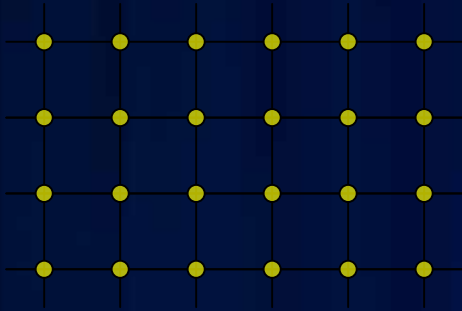
- Temperature varying with time



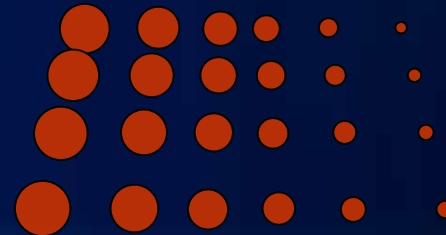
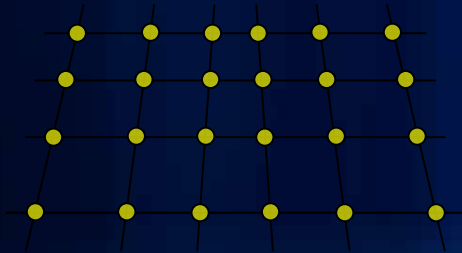
- Temperature varying with time and altitude



# Gridded Data



**Regular Grid**



**Irregular Grid**

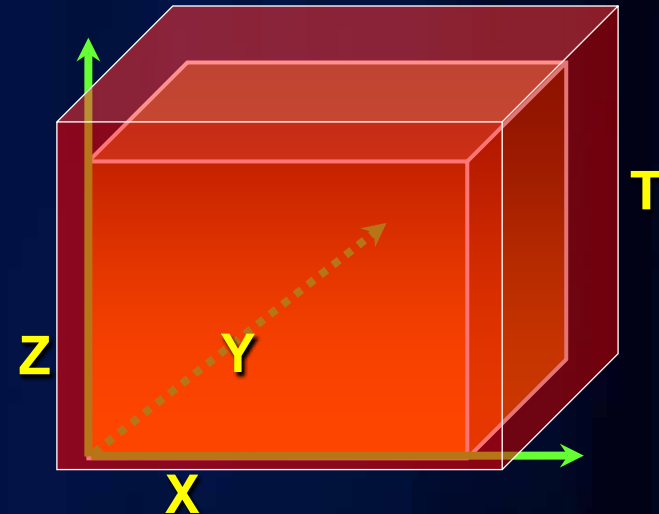


# Temporal/Multidimensional Data Formats

- NetCDF (network Common Data Form)
- HDF (4.x and previous releases), HDF-EOS, HDF5 (Hierarchical Data Format)
- GRIB, GRIB II (GRIdded Binary)

# Temporal Data in ArcGIS

- ArcGIS 9.2 reads/writes **netCDF**
- An array based data structure for storing multidimensional data.
- N-dimensional coordinates systems
  - X coordinate (e.g. longitude)
  - Y coordinate (e.g. latitude)
  - Z coordinate (e.g. altitude)
  - Time dimension
  - ... other dimensions
- Variables – support for multiple variables
  - Temperature, humidity, pressure, salinity, etc
- Geometry – implicit or explicit
  - Regular grid (implicit)
  - Irregular grid
  - Points



# What is NetCDF?

- **NetCDF** (network Common Data Form)  
A platform independent format for representing multi-dimensional array-orientated scientific data.
- **Self Describing**: a netCDF file includes information about the data it contains.
- **Direct Access**: a small subset of a large dataset may be accessed efficiently, without first reading through all the preceding data.
- **Sharable**: one writer and multiple readers may simultaneously access the same netCDF file.

NetCDF is relatively new to the GIS community but widely used by scientific communities for many years.

# Why netCDF?

Most commonly used format in the oceanographic and atmospheric science for observational data and numerical modeling

- The National Center for Atmospheric Research (NCAR)
- University Corporation for Atmospheric Research (UCAR)
- NOAA's Climate Diagnostics Center (CDC)
- Los Alamos National Laboratory (LANL)
- The National Center for Supercomputing Applications
- US Air Force and Navy
- Atmospheric Research in Australia
- Australia Defense
- UK Hydrographic Office
- NATO
- ...

# What is a NetCDF file?

- NetCDF is a binary file
- A NetCDF file consists of:
  - Global Attributes:** Describe the contents of the file
  - Dimensions:** Define the structure of the data (e.g Time, Depth, Latitude, Longitude)
  - Variables:** Holds the data in arrays shaped by Dimensions
  - Variable Attributes:** Describes the contents of each variable
- CDL (network Common Data form Language) description takes the following form

```
netCDF name {  
  dimensions: ...  
  variables: ...  
  data: ...  
}
```

# CDL File

## *The text representation of binary netCDF file*

```
netcdf filename {
dimensions:
    lat = 3 ;
    lon = 4 ;
    time = UNLIMITED ; // (2 currently)

variables:
    float lat(lat) ;
        lat:long_name = "Latitude" ;
        lat:units = "degrees_north" ;
    float lon(lon) ;
        lon:long_name = "Longitude" ;
        lon:units = "degrees_east" ;
    int time(time) ;
        time:long_name = "Time" ;
        time:units = "days since 1895-01-01" ;
        time:calendar = "gregorian" ;
    float rainfall(time, lat, lon) ;
        rainfall:long_name = "Precipitation" ;
        rainfall:units = "mm yr-1" ;
        rainfall:missing_value = -9999.f ;

// global attributes:
    :title = "Historical Climate Scenarios" ;
    :Conventions = "CF-1.0" ;

data:
    lat = 48.75, 48.25, 47.75;
    lon = -124.25, -123.75, -123.25, -122.75;
    time = 364, 730;
    rainfall =
        761, 1265, 2184, 1812, 1405, 688, 366, 269, 328, 455, 524, 877,
        1019, 714, 865, 697, 927, 926, 1452, 626, 275, 221, 196, 223;
}
```

# 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);
```

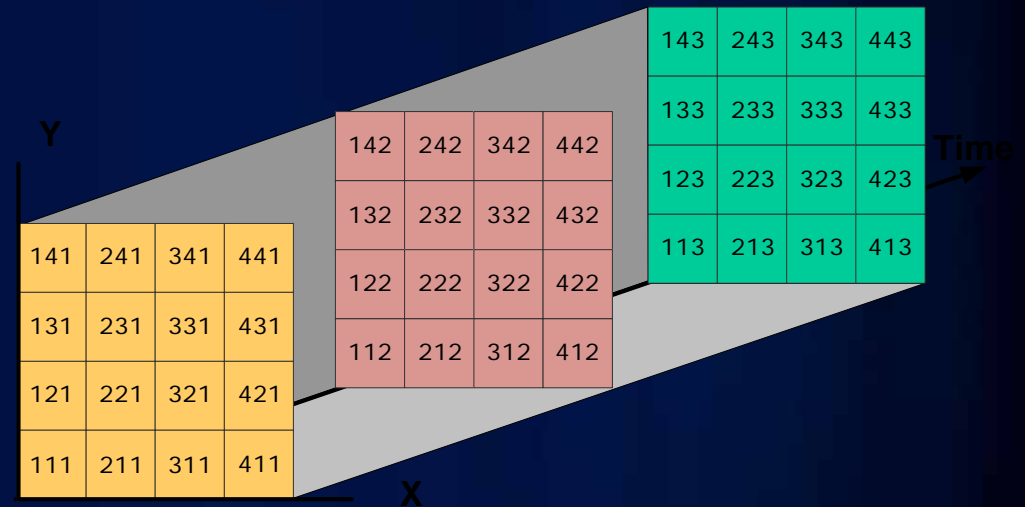
```
data:
```

```
    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:
```

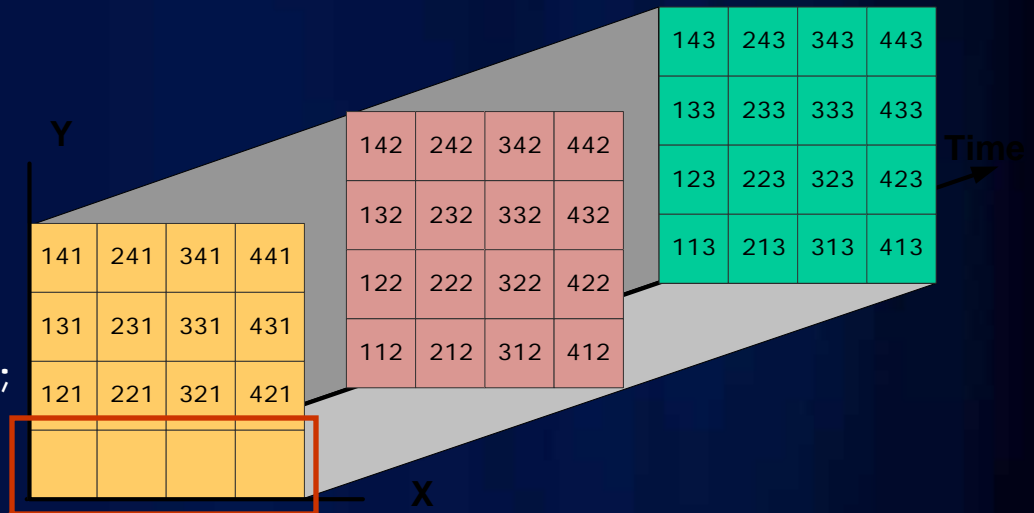
```
  X = 10, 20, 30, 40;
```

```
  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;
```

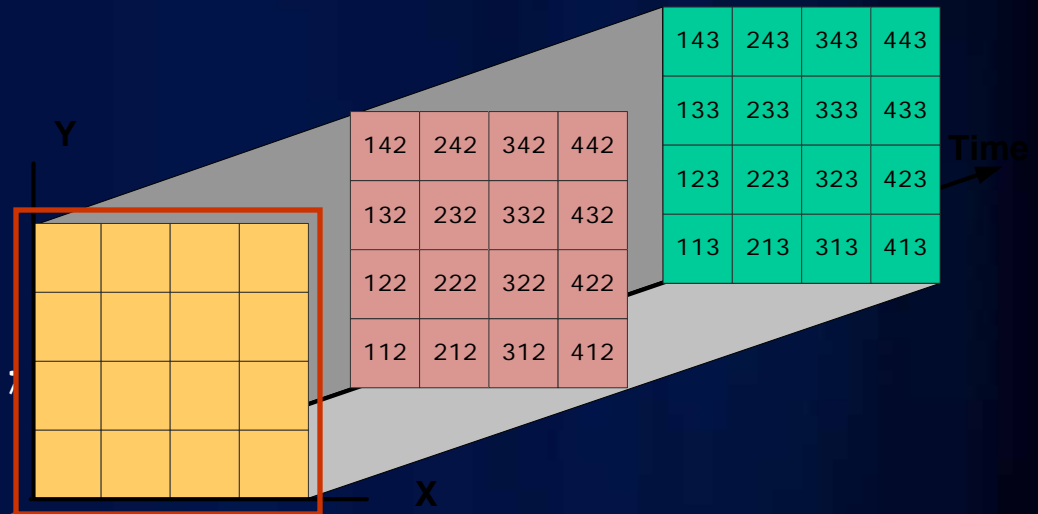
```
  Time = 31, 59, 90;
```

```
  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,
```

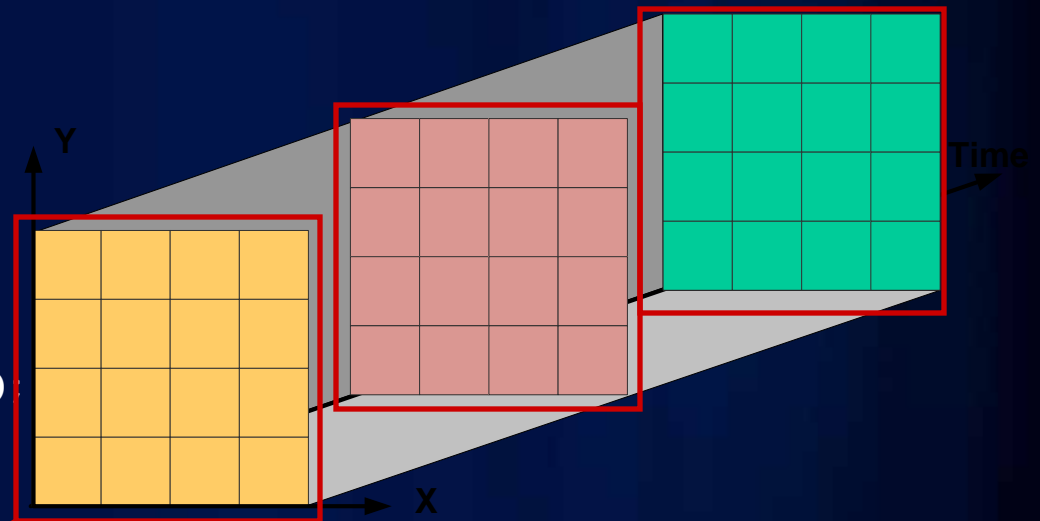
```
112,212,312,412,122,222,322,422,
```

```
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 Conventions

- CF Convention (*Recommended*)
- COARDS Convention (*1995 standard that CF Conventions extends and generalizes*)
- GDT Convention (*1999 standard that CF Conventions extends and generalizes*)
- CDC Convention (*for gridded data, compatible with but more restrictive than COARDS*)
- NCAR-RAF Convention for Aircraft Data
- AMBER Trajectory Convention for molecular dynamics simulations
- NUWG Convention (*1992-1995 effort to create some observational data conventions*)
- PMEL-EPIC Convention
- GDV Convention (*deprecated*)

# CF Convention

## Climate and Forecast (CF) Convention

<http://cf-pcmdi.llnl.gov/>

Initially developed for

- Climate and forecast data
- Atmosphere, surface and ocean model-generated data
- Also for observational datasets
- The CF conventions generalize and extend the COARDS (Cooperative Ocean/Atmosphere Research Data Service) convention.
- CF is now the most widely used conventions for geospatial netCDF data. **It has the best coordinate system handling.**

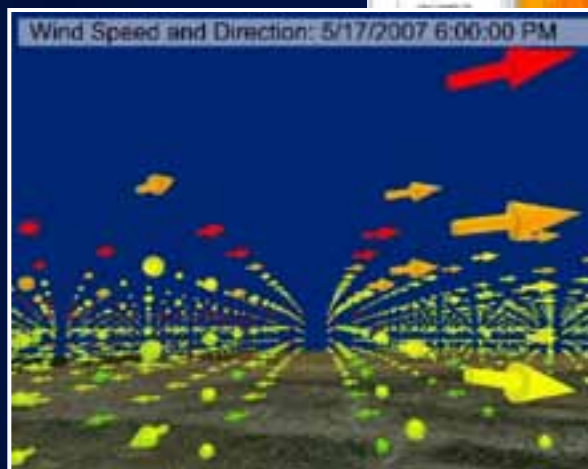
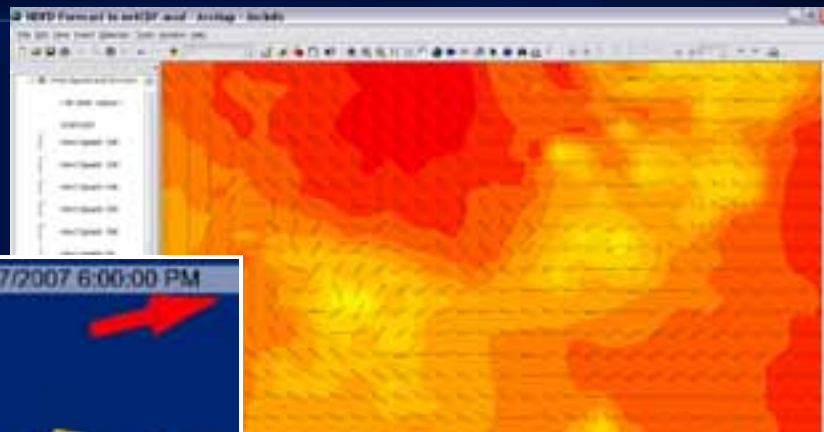
# NetCDF and Coordinate Systems

- 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 1.5 conventions currently supports thirteen predefined coordinate systems ([Appendix F: Grid Mappings](#))
- Undefined
  - If not GCS or PCS
- ArcGIS writes (and recognizes) PE String as a variable attribute.

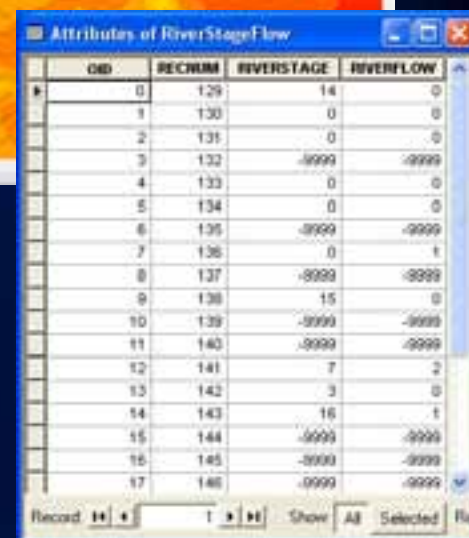
# Ingesting netCDF data in ArcGIS

- NetCDF data is accessed as

- Raster
- Feature
- Table



- Direct read
- Exports GIS data to netCDF

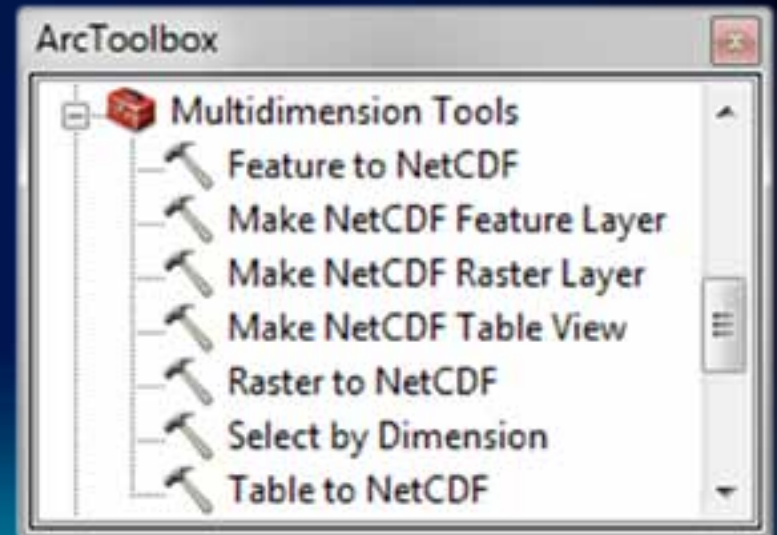
A screenshot of a NetCDF data visualization in ArcGIS. The main window displays a table of attributes. The title bar of the window reads "Attributes of RiverStageFlow". The table has four columns: "OID", "RECURM", "RIVERSTAGE", and "RIVERFLOW". The data is as follows:

OID	RECURM	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

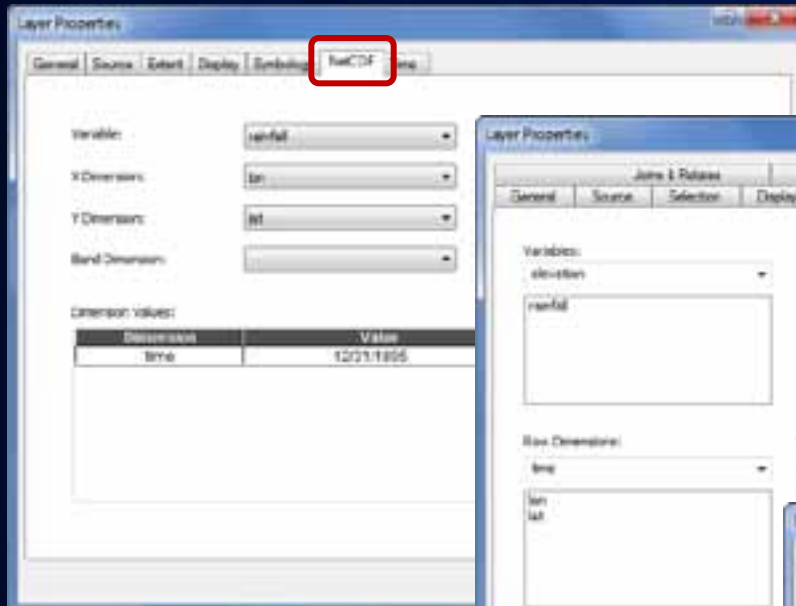
# NetCDF Tools

## Toolbox: Multidimension Tools

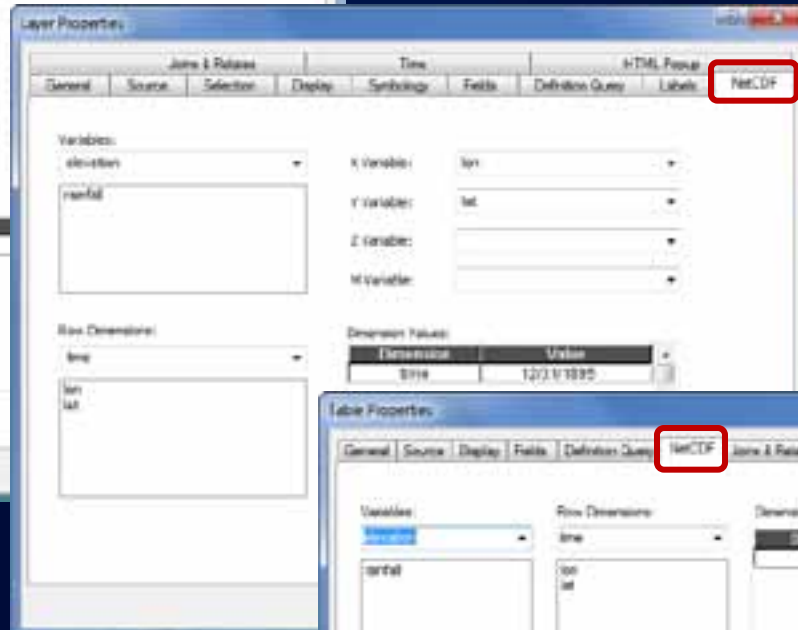
- Make NetCDF Raster Layer
- Make NetCDF Feature Layer
- Make NetCDF Table View
- Raster to NetCDF
- Feature to NetCDF
- Table to NetCDF
- Select by Dimension



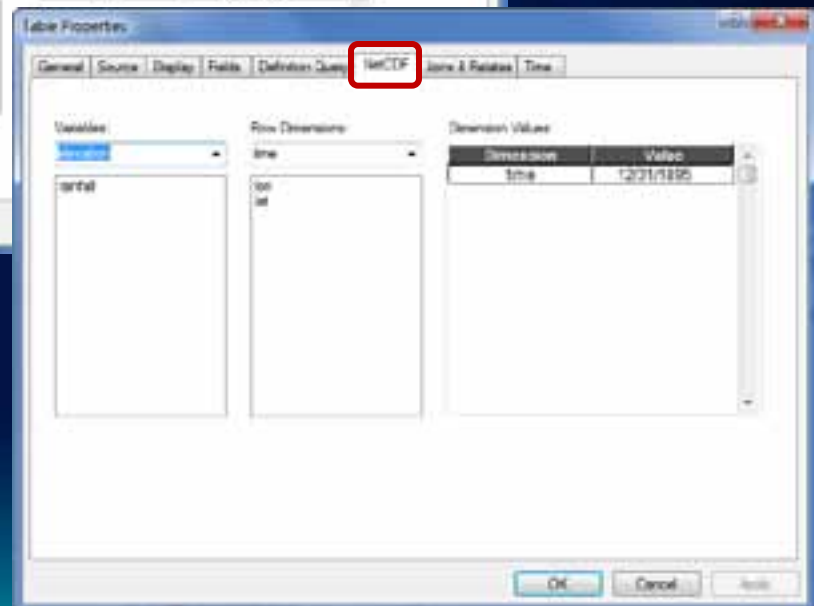
# NetCDF Layer/Table Properties



Raster



Feature



Table



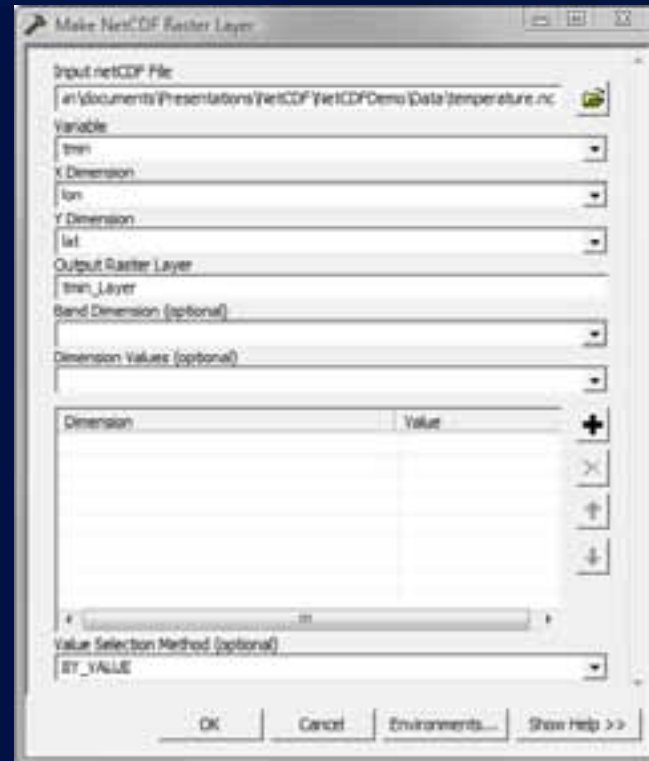
# Using NetCDF Data

## 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.)

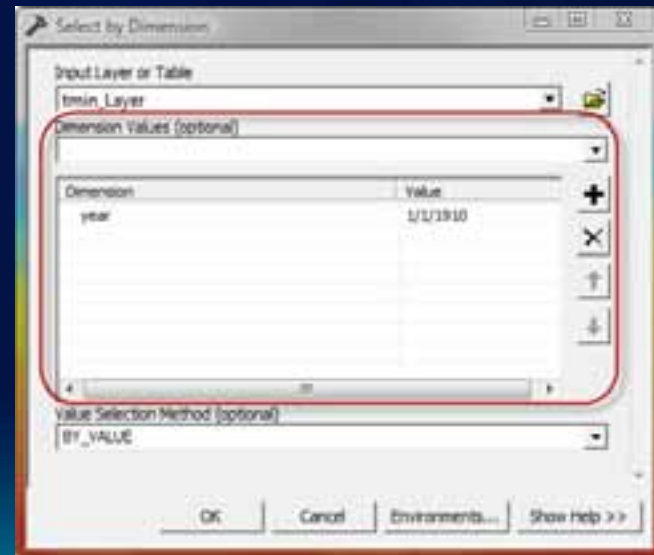
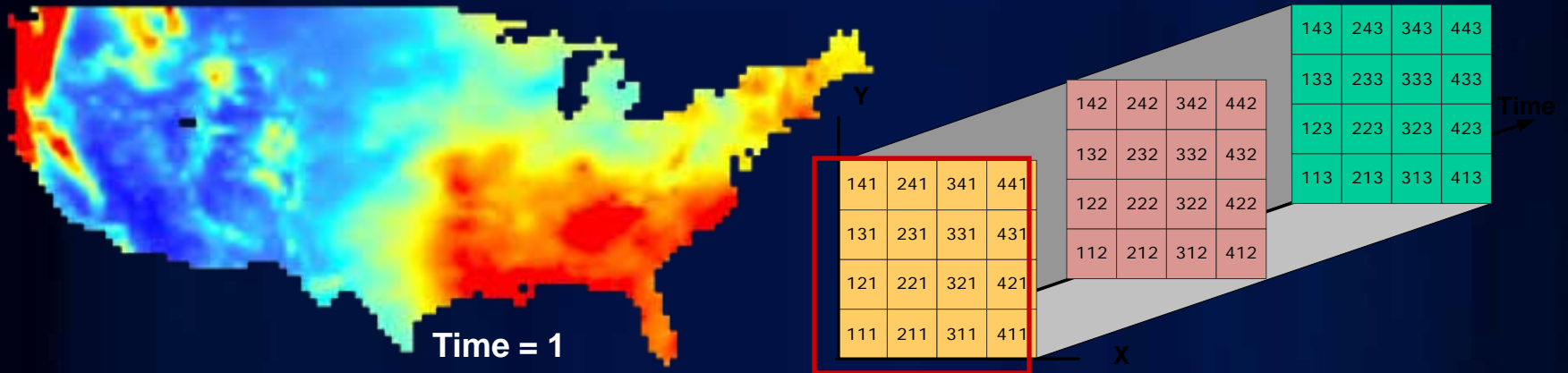
# Making a netCDF Raster Layer

- Drag and drop
- Use the tool



Usage: MakeNetCDFRasterLayer <in\_netCDF\_file> <variable> <x\_dimension>  
<y\_dimension> <out\_raster\_layer> {band\_dimension} {Dimension  
{Value};Dimension {Value}...} {BY\_VALUE | BY\_INDEX}

# Changing Time Slice



# Creating a Time Series / Profile at a Location

1. Open MakeNetCDFTableView
2. Specify a netCDF file
3. Specify a variable
4. Specify an output name
5. Specify a row dimension
6. Specify a longitude value
7. Specify a latitude value
8. Click OK



**Make NetCDF Table View**

Input netCDF file: C:\D:\ArcGIS\workspace\2\city\_temperature.nc 2

Variables: 3

Output Table View: temperature\_view 4

Row Dimension (optional): year 5

Dimension Values (optional):

Dimension: Value 6

lon: -111.75 7

lat: 45.75

Value Selection Method (optional): BY\_VALUE

OK 8 Cancel Environment... Show...

**Attributes of temperature\_View**

	OID	year	tmin
	0	1/1/1875	-3.89956
	1	1/1/1880	-4.197895
	2	1/1/1885	-5.583697
	3	1/1/1890	-3.631523
	4	1/1/1895	-4.16319
	5	1/1/1900	-3.276012
	6	1/1/1905	-4.90945
	7	1/1/1910	-4.568613
	8	1/1/1915	-3.715039
	9	1/1/1920	-4.005638
	10	1/1/1925	-4.278658
	11	1/1/1930	-4.10734
	12	1/1/1935	-4.335642
	13	1/1/1940	1.435794
	14	1/1/1945	1.500879
	15	1/1/1950	0.87678
	16	1/1/1955	1.589518
	17	1/1/1960	1.045807
	18	1/1/1965	1.211914
	19	1/1/1970	1.46302
	20	1/1/1975	2.244391
	21	1/1/1980	2.900941
	22	1/1/1985	1.702047
	23	1/1/1990	2.347241

Record: 1

# Dimensionality

- The number of dimensions in a variable
  - Scalar – No dimension
  - Vector – One dimension
  - Matrix – Two dimensions
- To create a raster
  - A variable must have two or more dimensions
  - Data must be equally spaced along longitude or X axis
  - Data must be equally spaced along latitude or Y axis
- To create a feature or table
  - A variable must have one or more dimensions

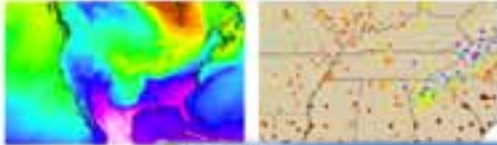
# Help on netCDF

The image shows two overlapping screenshots of the ArcGIS 10 Help interface. The top screenshot displays the 'What is netCDF data?' page, which includes a description of netCDF as a file format for storing multidimensional scientific data and two small maps. The bottom screenshot shows the 'An overview of the Multidimension toolbox' page, which lists various tools for working with netCDF data. A red arrow points from the 'netCDF' link in the left sidebar of the top screenshot to the 'Overview of the Multidimension toolbox' link in the left sidebar of the bottom screenshot.

## What is netCDF data?

ArcGIS 10

NetCDF (network Common Data Form) is a file format for storing multidimensional scientific data (variables) such as temperature, humidity, pressure, wind speed, and direction. Each of these variables can be displayed through a dimension (such as time) in ArcGIS by making a layer or table view from the netCDF file.



[Learn more about netCDF](#)

Several organizations use netCDF as a standard v

[Learn more about when](#)

## Related Topics

- [Essential netCDF vocabulary](#)
- [Fundamentals of netCDF data storage](#)
- [How ArcGIS represents netCDF data](#)
- [Managing netCDF data](#)
- [Mapping and visualizing netCDF data](#)
- [Tutorial](#)

## An overview of the Multidimension toolbox

ArcGIS 10

The Multidimension toolbox contains tools that operate on netCDF data. You can use these tools to make a netCDF raster layer, feature layer, or table view; to convert to netCDF from a raster, feature, or table; and to select a dimension of a netCDF layer or table.

[Learn more about netCDF data](#)

Tool	Description
<a href="#">Feature to NetCDF</a>	Converts a point feature class to a netCDF file.
<a href="#">Make NetCDF Feature Layer</a>	Makes a feature layer from a netCDF file.
<a href="#">Make NetCDF Raster Layer</a>	Makes a raster layer from a netCDF file.
<a href="#">Make NetCDF Table View</a>	Makes a table view from a netCDF file.
<a href="#">Raster to NetCDF</a>	Converts a raster dataset to a netCDF file.
<a href="#">Select by Dimension</a>	Updates the netCDF layer display or netCDF table view based on the dimension value.
<a href="#">Table to NetCDF</a>	Converts a table to a netCDF file.

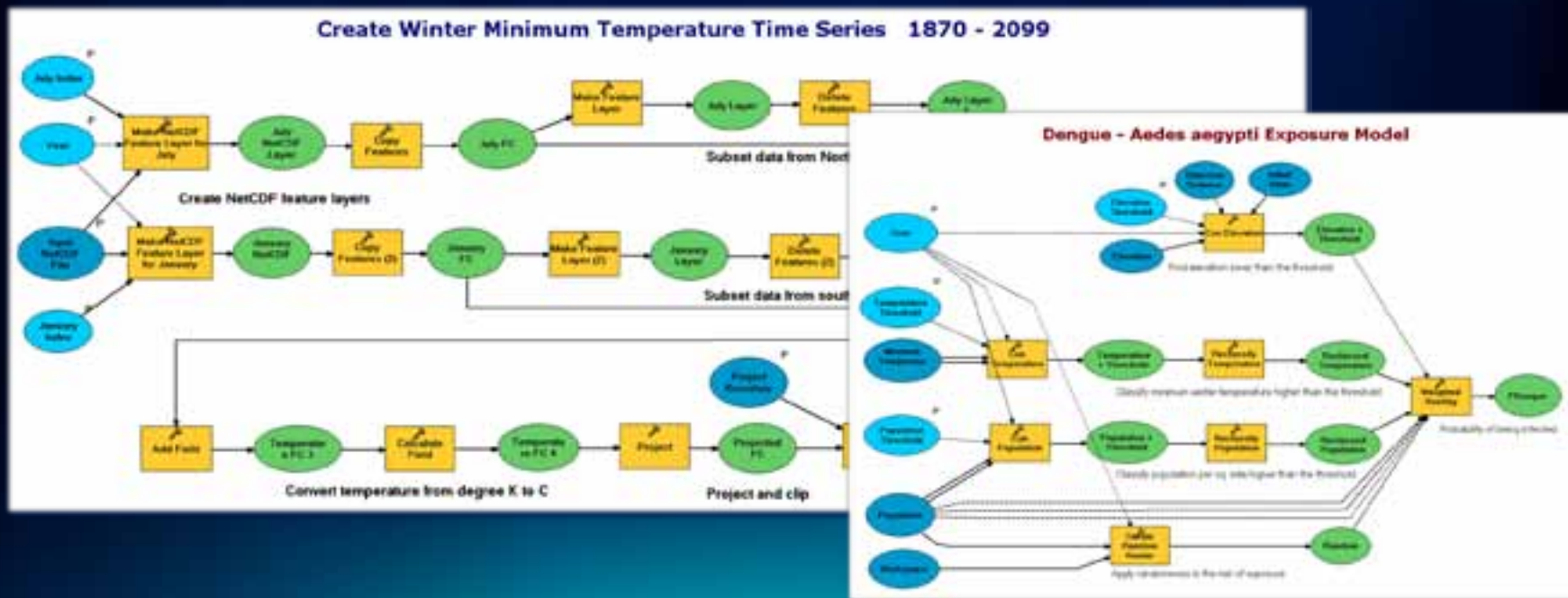
Multidimension tools

## Related Topics



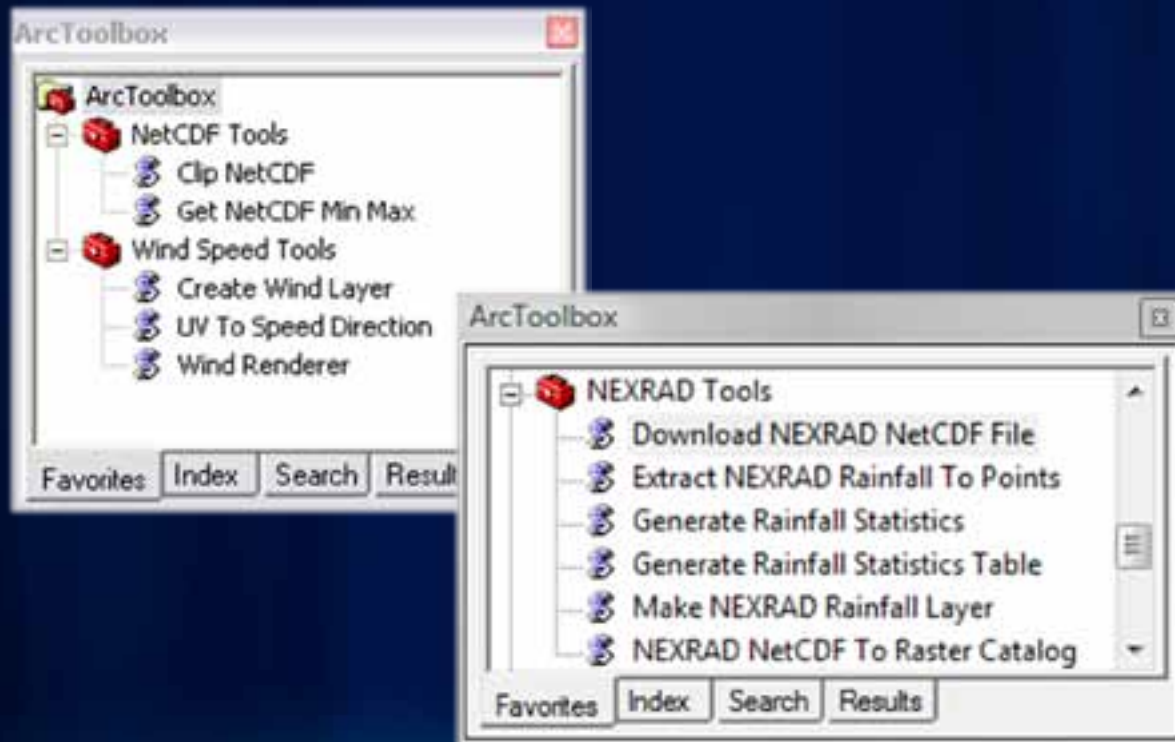
# Spatial and Temporal Analysis

- Several hundreds analytical tools available for raster, features, and table
- Temporal Modeling
  - Looping and iteration in ModelBuilder and Python



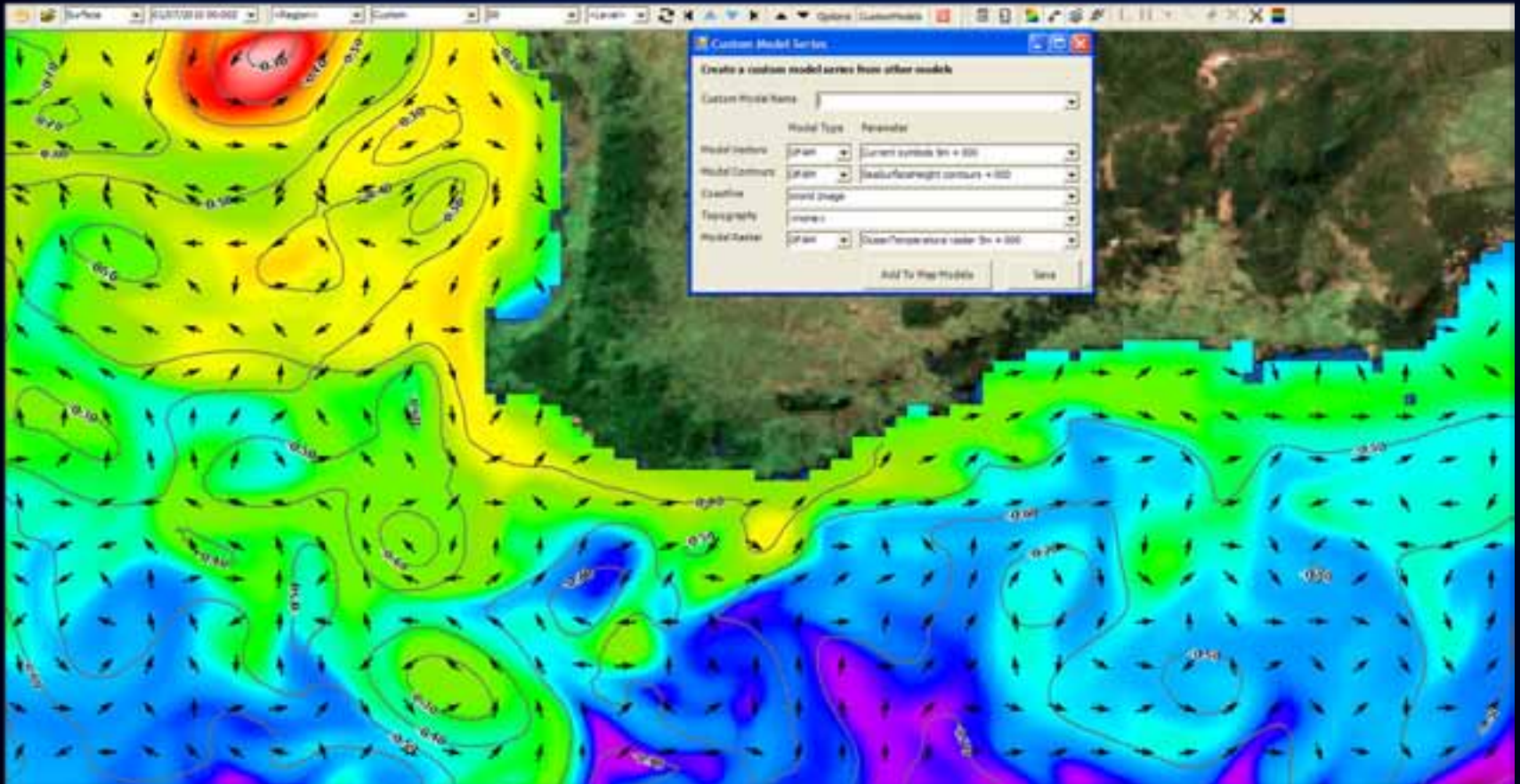
# Script Tools of interest

- Python is used to build custom tools for specific tasks or datasets



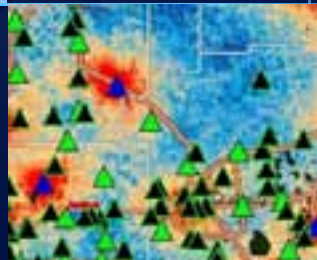
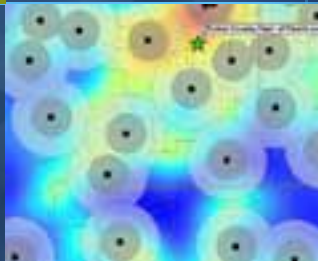


## Ocean Model Forecast – Custom Display



**Source: Hydrography and METOC Branch, Royal Australian Navy.**

# Demo : NetCDF data in ArcGIS



**...Thank You!**

**Questions?**

Please fill out the evaluation at  
[www.esri.com/sessionevals](http://www.esri.com/sessionevals)

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