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Technical Workshops | July 2011

NetCDF Data in Weather and Climate Applications

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Outline

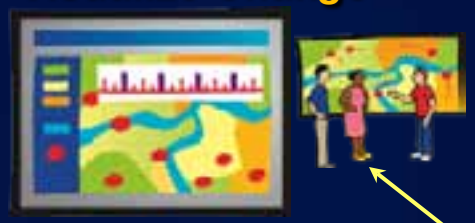
- Multidimensional data
- netCDF
- netCDF in ArcGIS
- Working with netCDF
- Help on netCDF

GIS Integration of Time

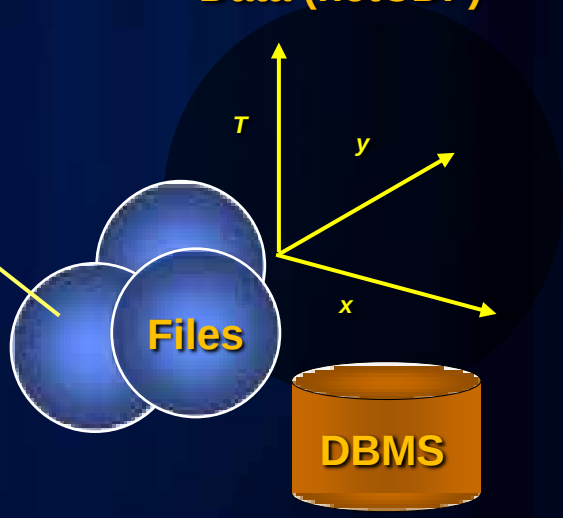
New Ways to Manage, Visualize & Analyze Geography

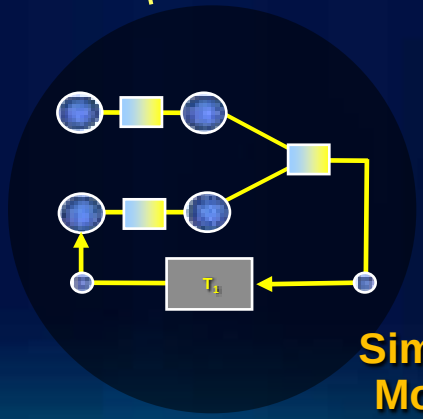
- Extended Data Model
- Tools for Manipulation
  - Query
  - Visualization
    - Animation
    - Charting
  - Iterative Processing
  - Tracking Analysis
  - nDim Forecast Models
  - Change Analysis

Visualize Change



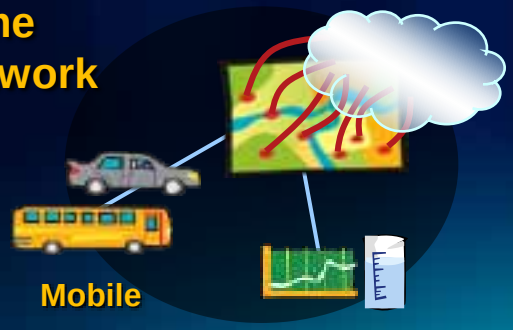
Multi Dimensional Data (netCDF)





Simulation Modeling

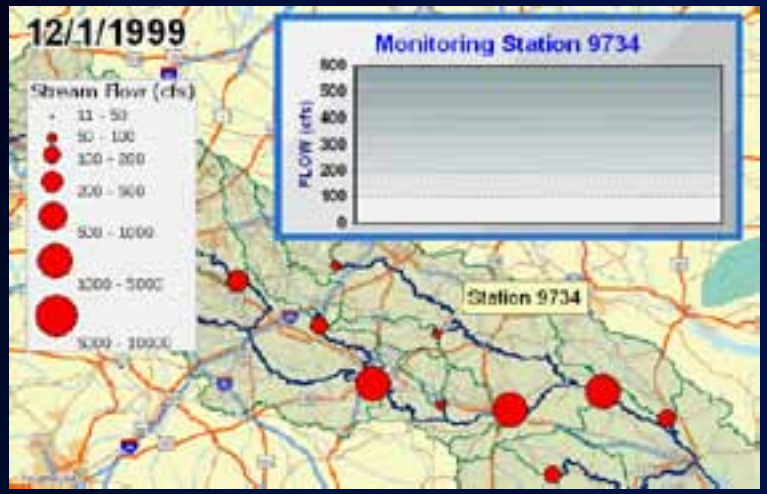
Real Time Sensor Network



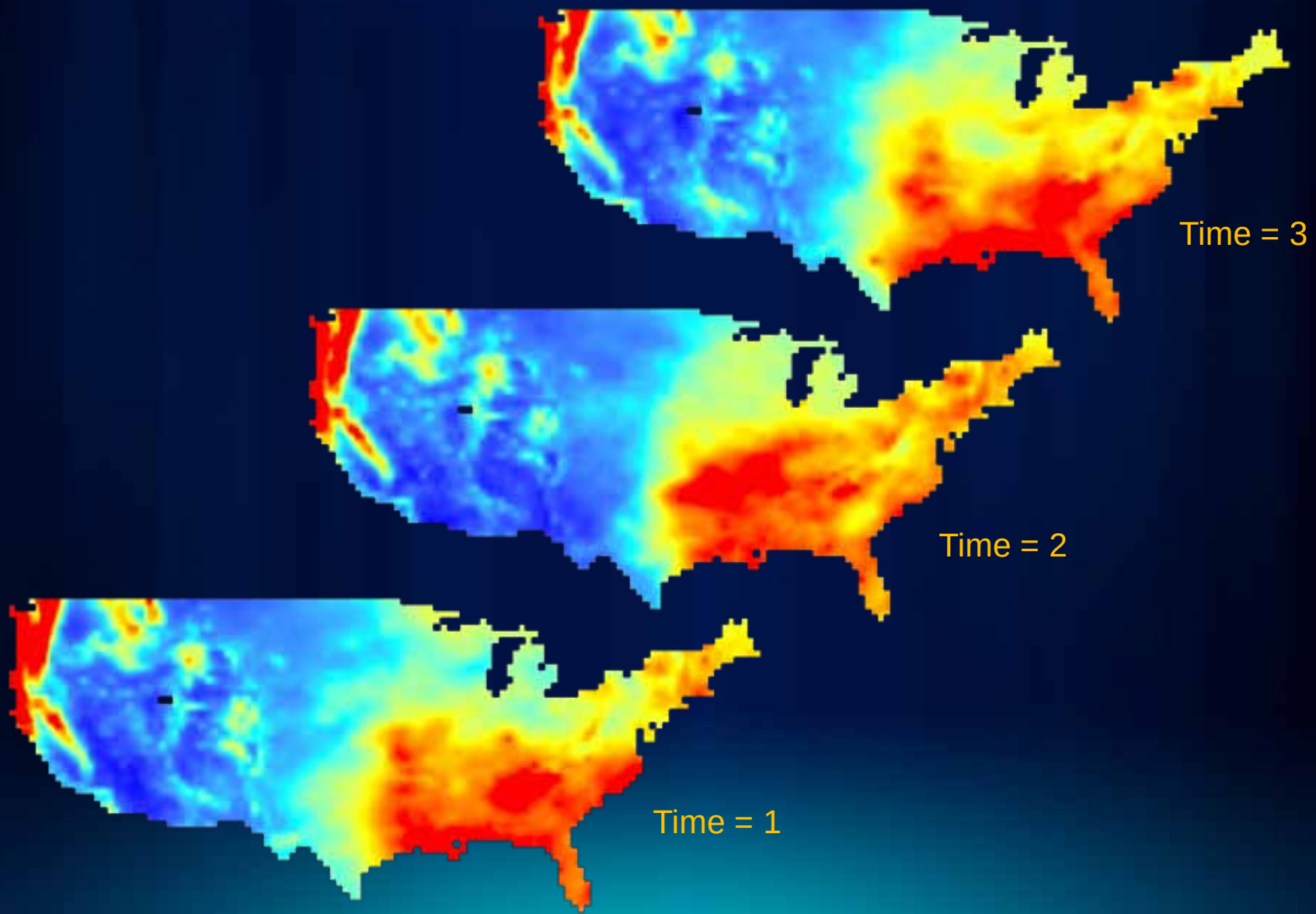
Mobile

Stationary

Multidimensional Data



Multidimensional Data

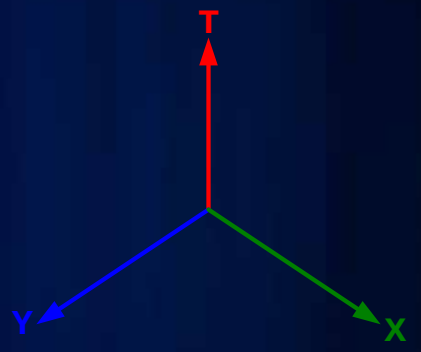


Multidimensional Data

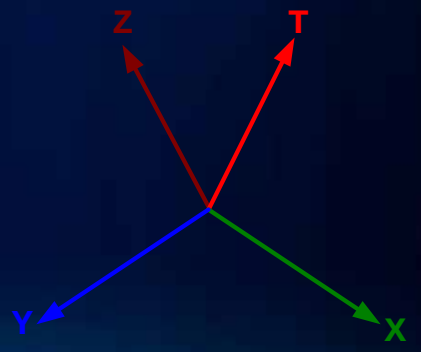
Multidimensional Data

Data cube (3D) or hypercube (4D,5D…)

- Temperature varying with time



- Temperature varying with time and altitude



Gridded Data

Regular Grid

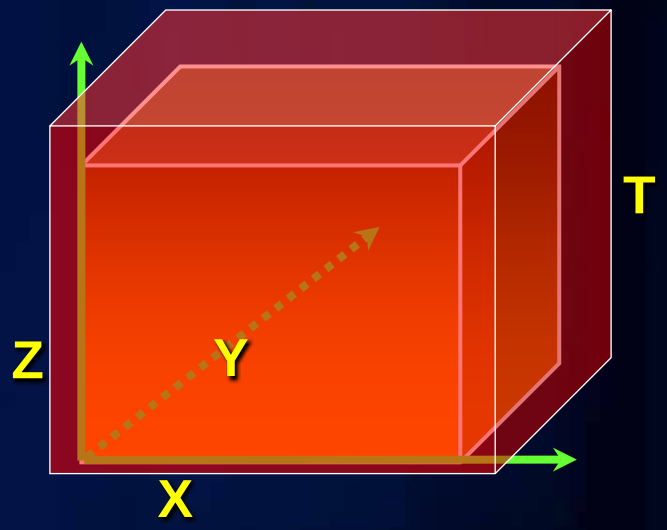
Irregular Grid

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: ...
}
```

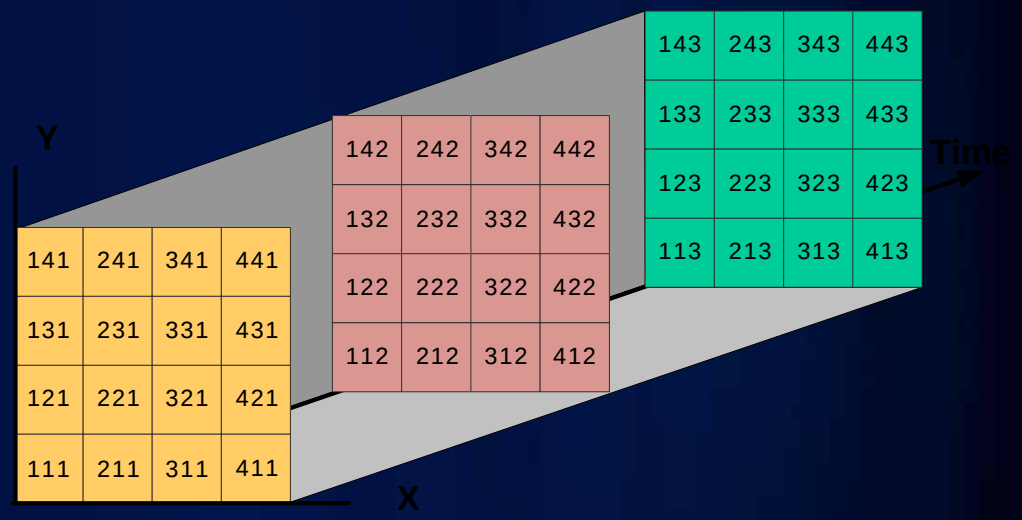
CDL File

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;
}
```

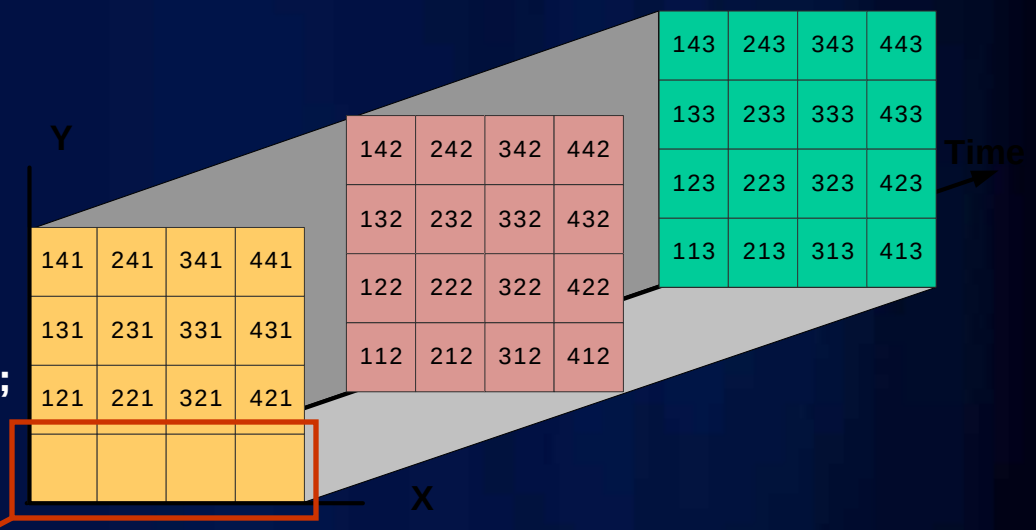
Storing Data in a netCDF File

```
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;
}
```



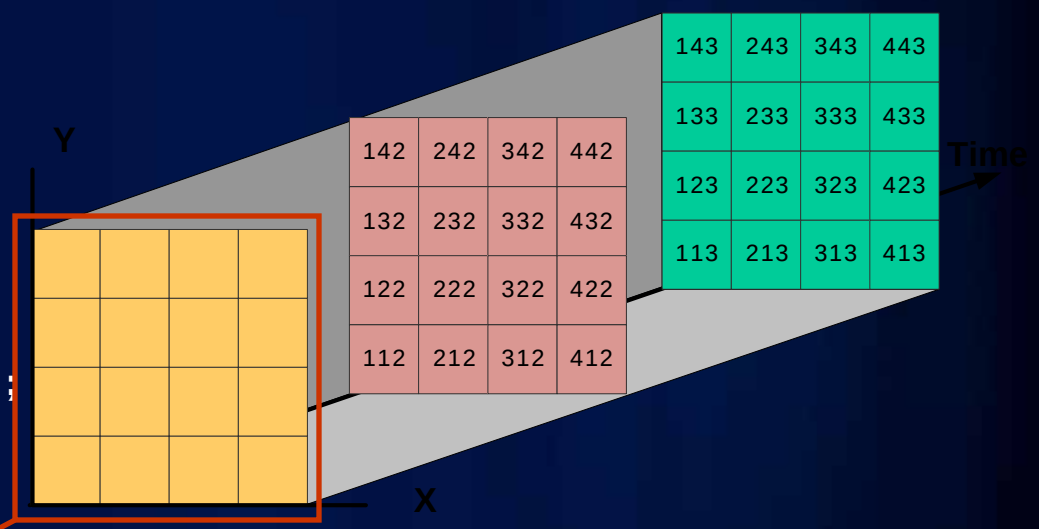
Time = 1

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;
}
```



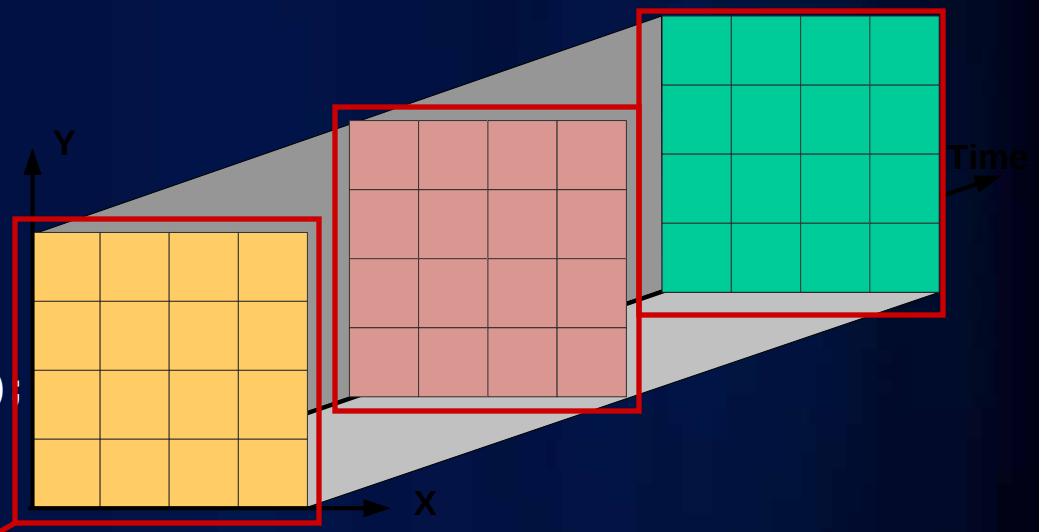
Time = 1

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.

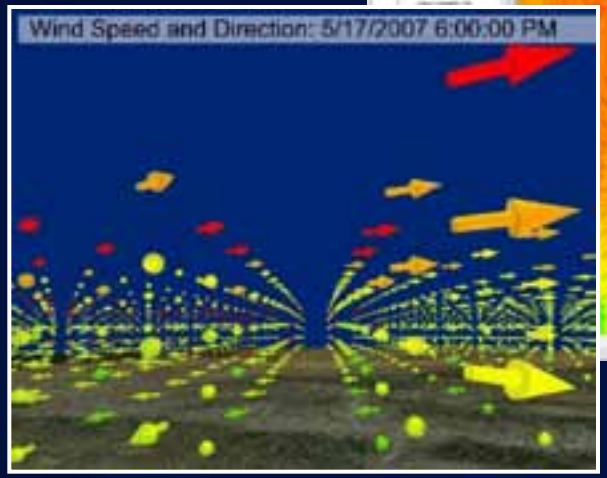
- CF is now the most widely used conventions for geospatial netCDF data. It has the best coordinate system handling.

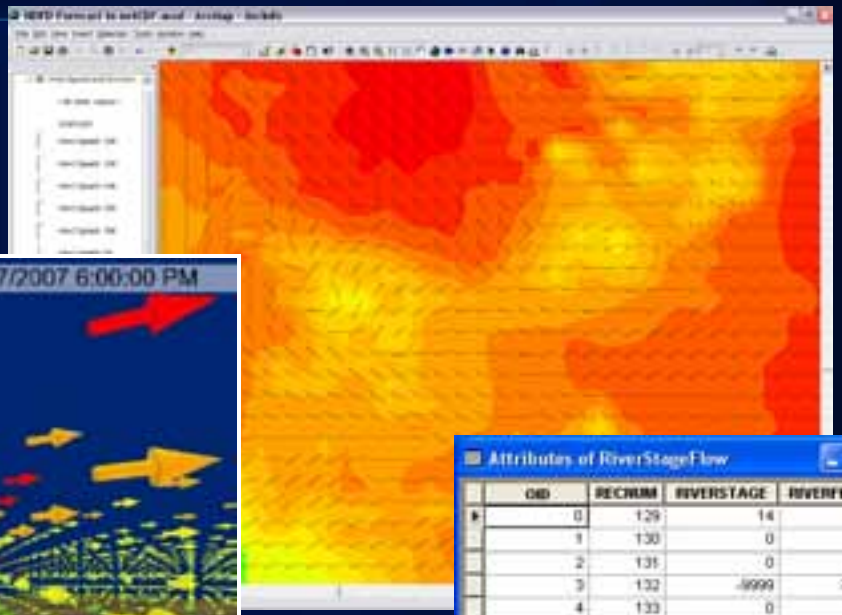
NetCDF and Coordinate Systems

- 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

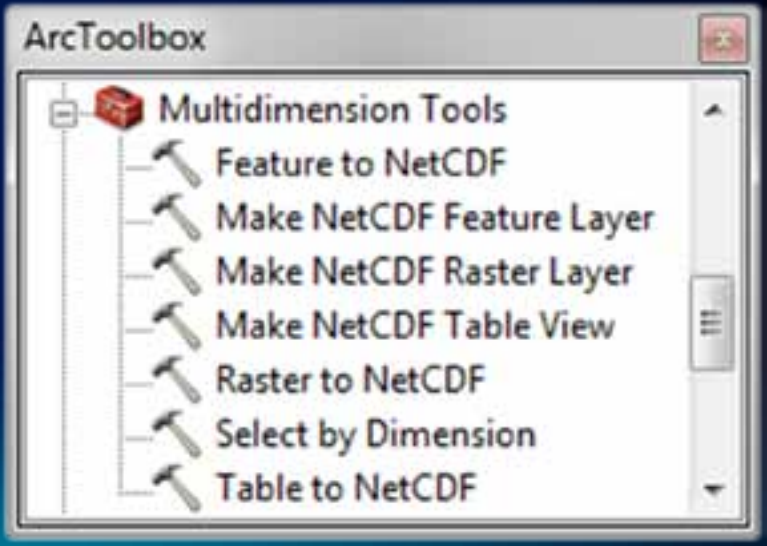
NetCDF Tools

Toolbox: Multidimension Tools

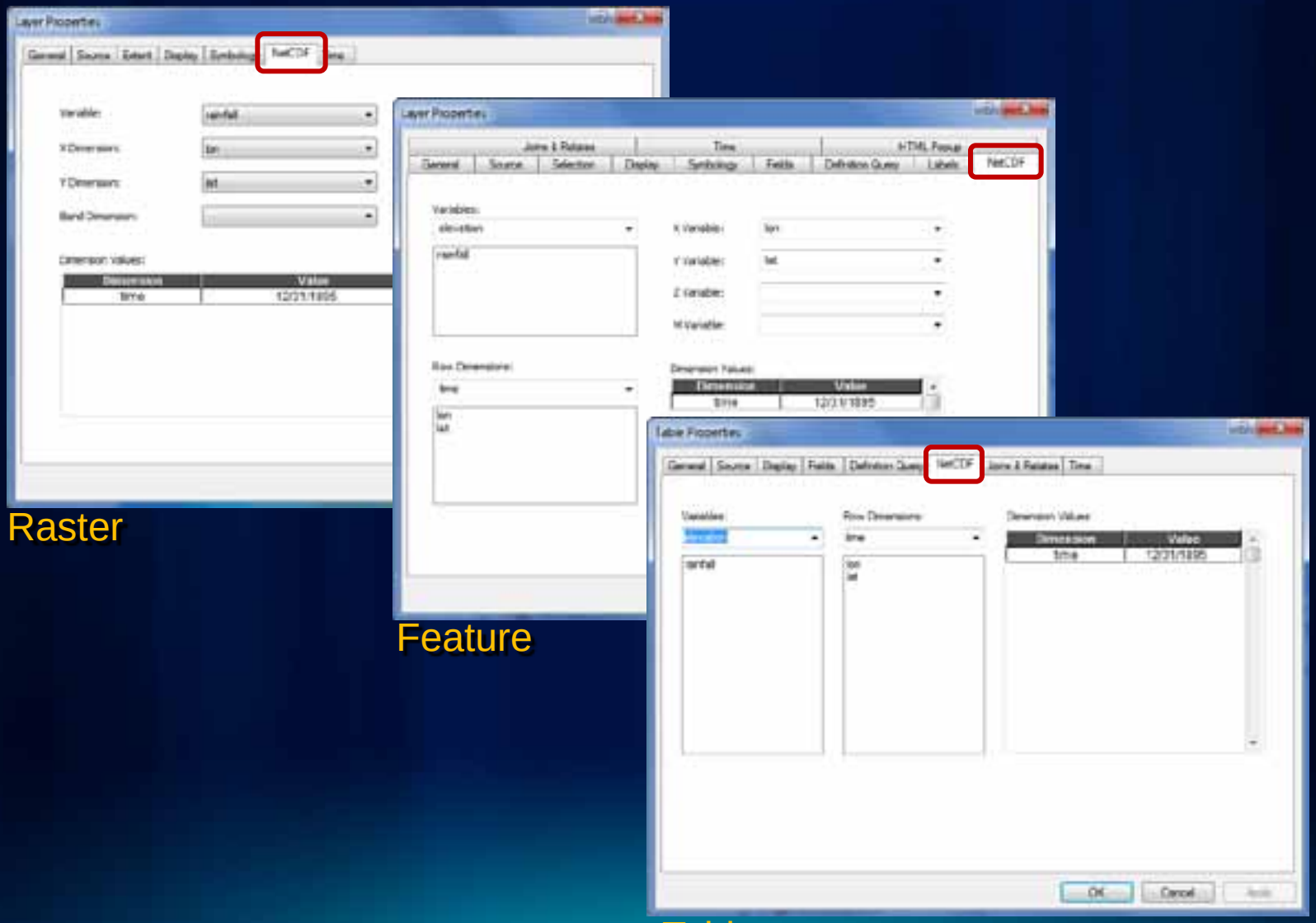
- Make NetCDF Raster Layer
- Make NetCDF Feature Layer
- Make NetCDF Table View

- Raster to NetCDF
- Feature to NetCDF
- Table to NetCDF

- Select by Dimension



NetCDF Layer/Table Properties



Using NetCDF Data

Behaves the same as any layer or table

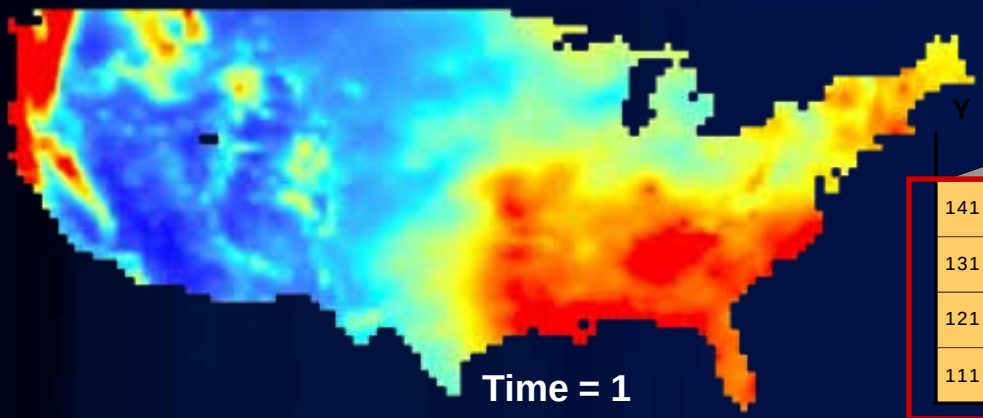
- Display
  - Same display tools for raster and feature layers will work on netCDF raster and netCDF feature layers.
- Graphing
  - Driven by the table just like any other chart.
- Animation
  - Multidimensional data can be animated through a dimension (e.g. time, pressure, elevation)
- Analysis Tools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

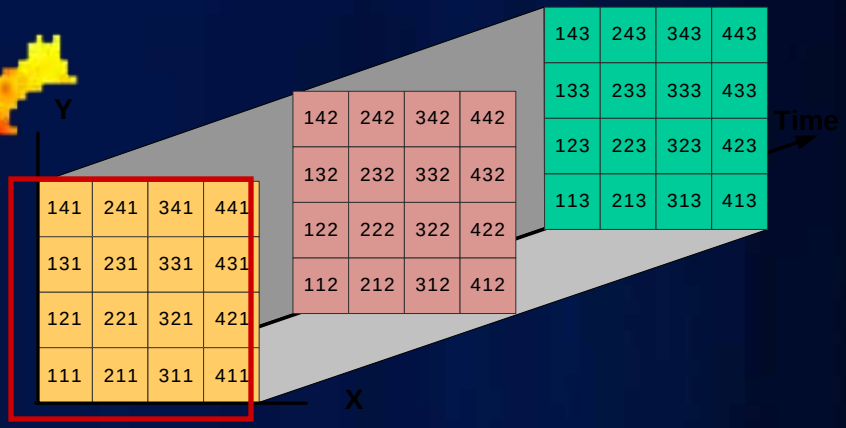
Making a netCDF Raster Layer

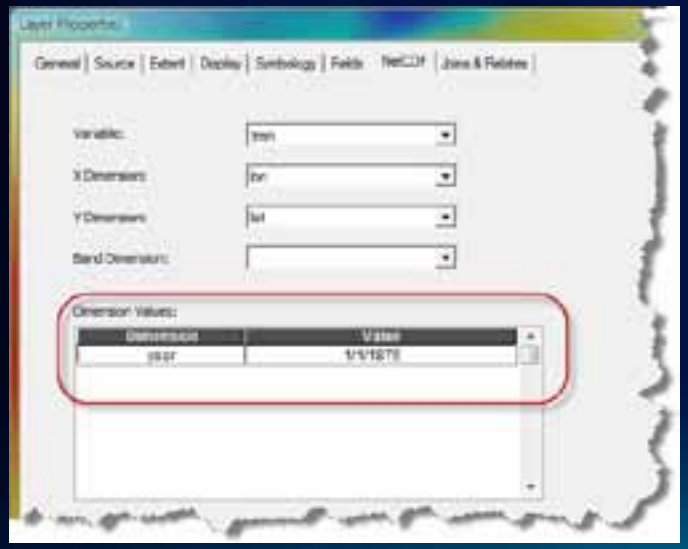
- Drag and drop
- Use the tool

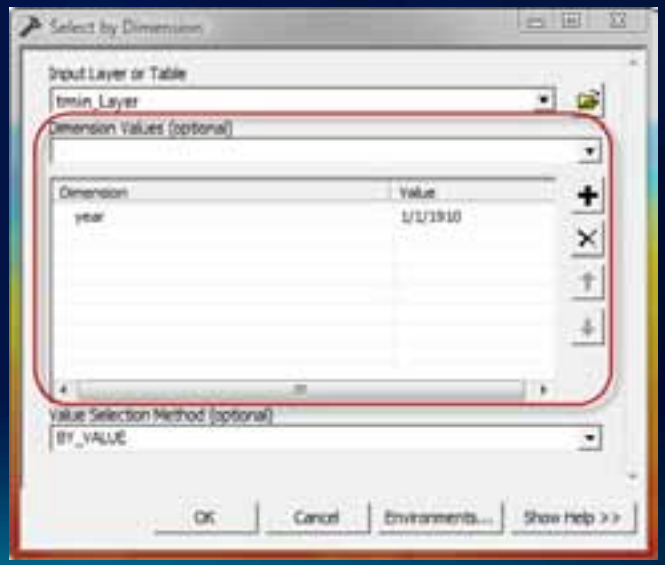
Usage: MakeNetCDFRasterLayer <in_netCDF_file> <variable> <x_dimension> <y_dimension> <out_raster_layer> {band_dimension} {Dimension {Value};Dimension {Value}...} {BY_VALUE | BY_INDEX}

Changing Time Slice



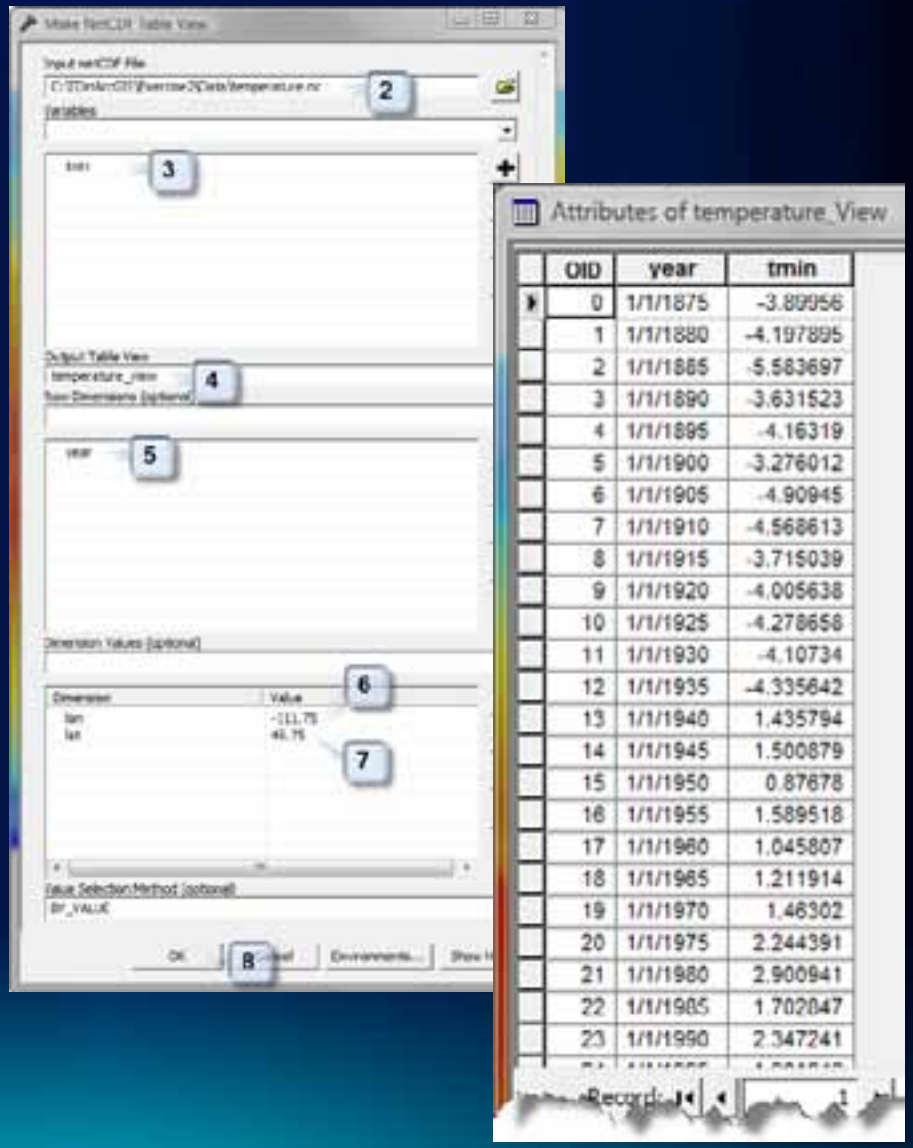






Creating a Time Series / Profile at a Location

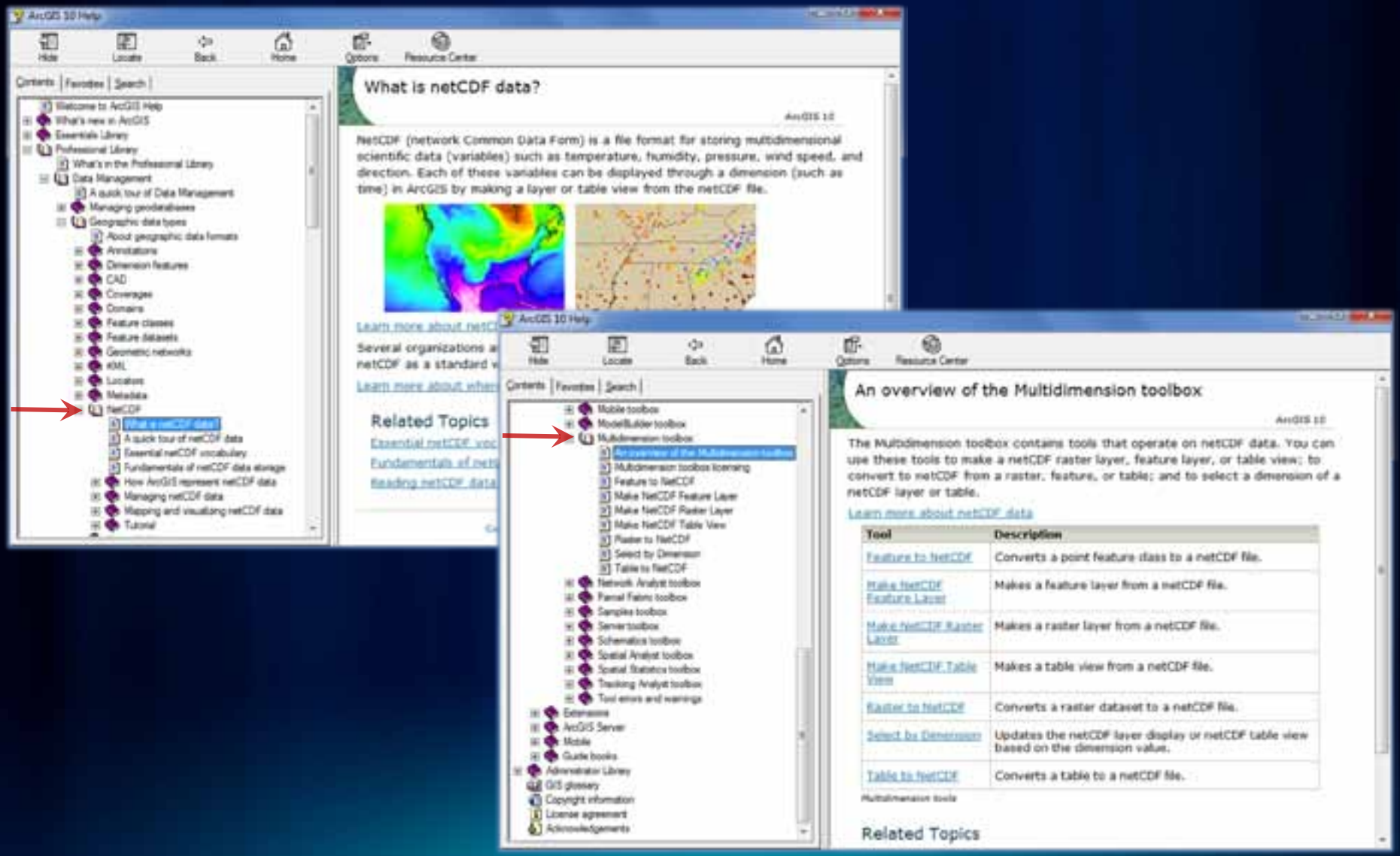
1. Open MakeNetCDFTableView
2. Specify a netCDF file
3. Specify a variable
4. Specify an output name
5. Specify a row dimension
6. Specify a longitude value
7. Specify a latitude value
8. Click OK



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

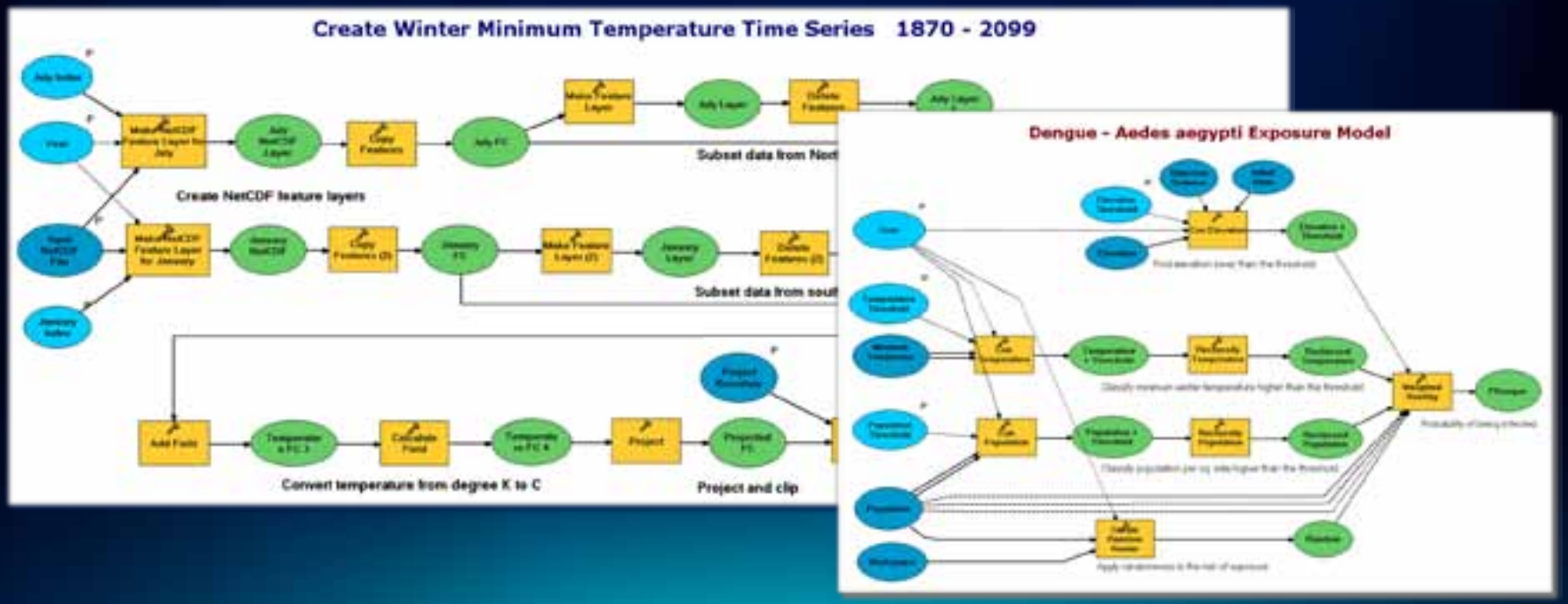
Help on netCDF



Spatial and Temporal Analysis

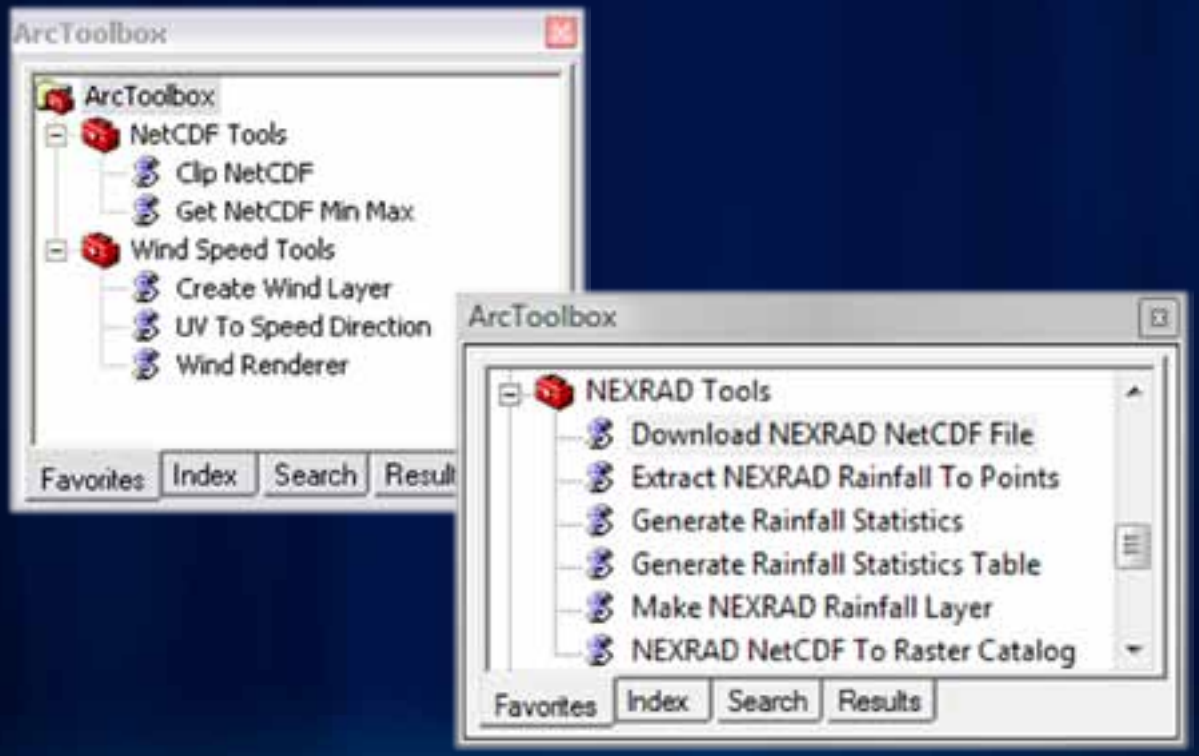
- Several hundreds analytical tools available for raster, features, and table

- Temporal Modeling
  - Looping and iteration in ModelBuilder and Python

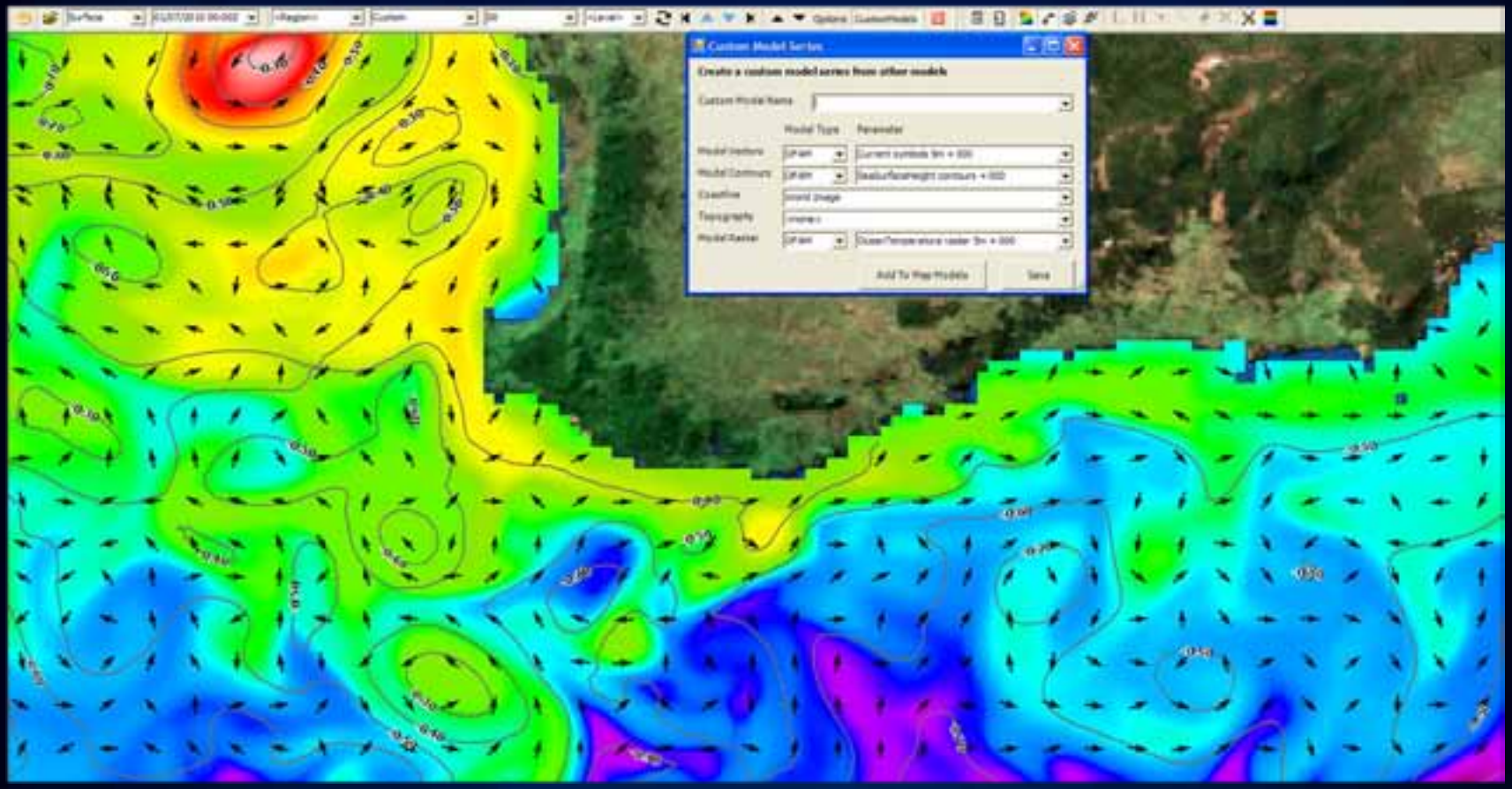


Script Tools of interest

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

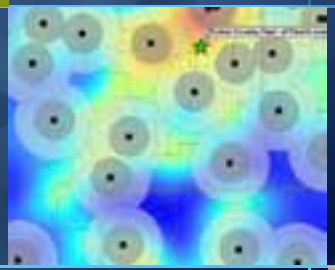


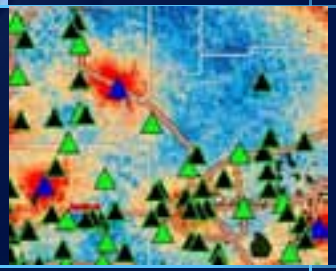
Ocean Model Forecast – Custom Display



Source: Hydrography and METOC Branch, Royal Australian Navy.

Demo : NetCDF data in ArcGIS





…Thank You!

Questions?

Please fill out the evaluation at
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