

# Working with HDF and netCDF Data in ArcGIS

## Tools and Case Studies

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HDF and HDF-EOS Workshop XIV, September 28-30, 2010, Champaign, IL

# Outline

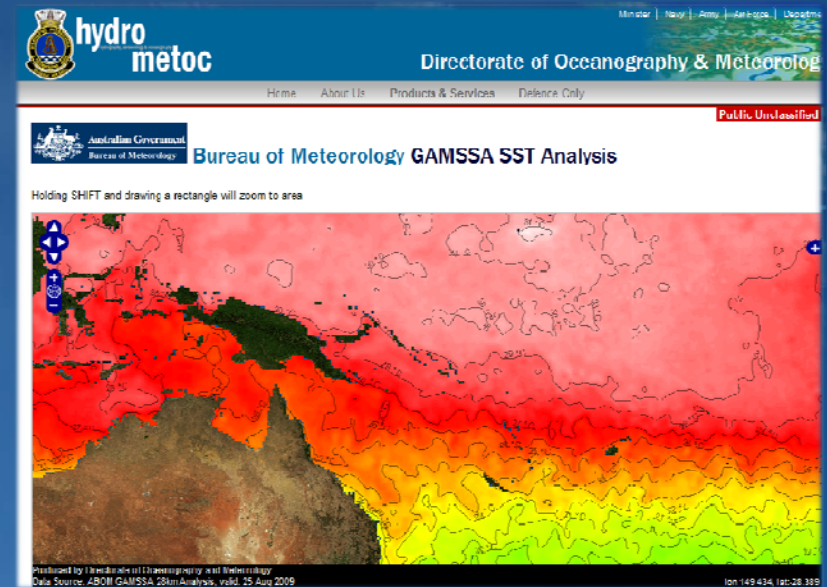
- **HDF and netCDF in ArcGIS**
- **Time in ArcGIS**
- **Performing Analysis**
  
- **Use Cases and Applications**
- **Script Tools**
- **Future Directions**

# HDF and netCDF in ArcGIS



# Scientific Data and ESRI

- Direct support - NetCDF and HDF
- THREDDS – a data server technology for multidimensional array data, integrated use by our customers
- Examples using ESRI technology
  - National Climate Data Center
  - National Weather Service
  - National Center for Atmospheric Research
  - Air Force Weather
  - Australian Navy
  - Australian Bur.of Met.
  - UK Met Office





# HDF4 and HDF5 Support in ArcGIS

The screenshot displays the ArcGIS interface with several windows open. A red box highlights the 'Add Data' button in the top toolbar. The 'Subdataset Selection' dialog box is open, showing a list of subdatasets with their IDs and descriptions. The 'Table of Contents' panel is also open, showing a list of layers with their names and value ranges. The main map display shows a global map with a color scale representing temperature, ranging from blue (low) to red (high).

**Subdataset Selection**

This file contains multiple datasets. Selecting one dataset will display as a single raster layer. Selecting multiple datasets allows to display as a group layer or RGB layer. You must select at least one dataset in the list.

Subdataset ID	Description
subdataset 0	[720x1440] Daytime Land
subdataset 1	[720x1440] Nighttime Land

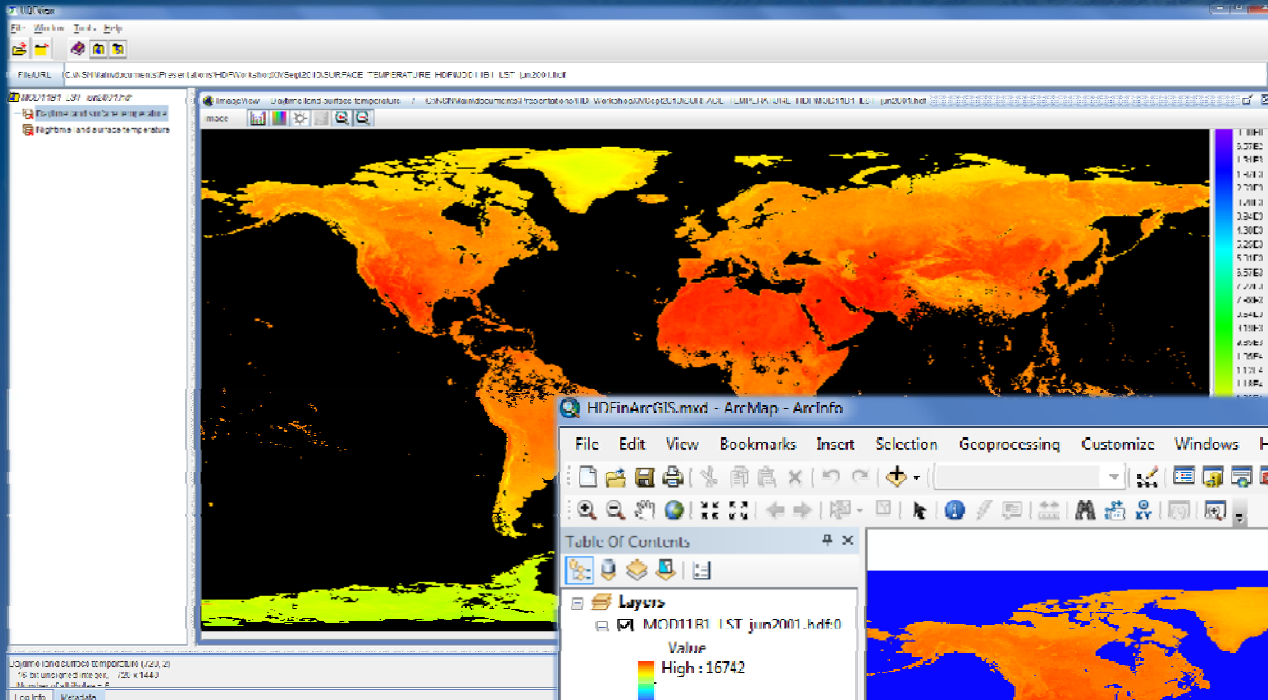
**Table of Contents**

- Layers
  - MOD11B1\_LST\_jun2001.hdf:0
    - Value
    - High : 16742
    - Low : 0
  - MOD11B1\_LST\_nov2001.hdf:0
    - Value
    - High : 16756
    - Low : 0

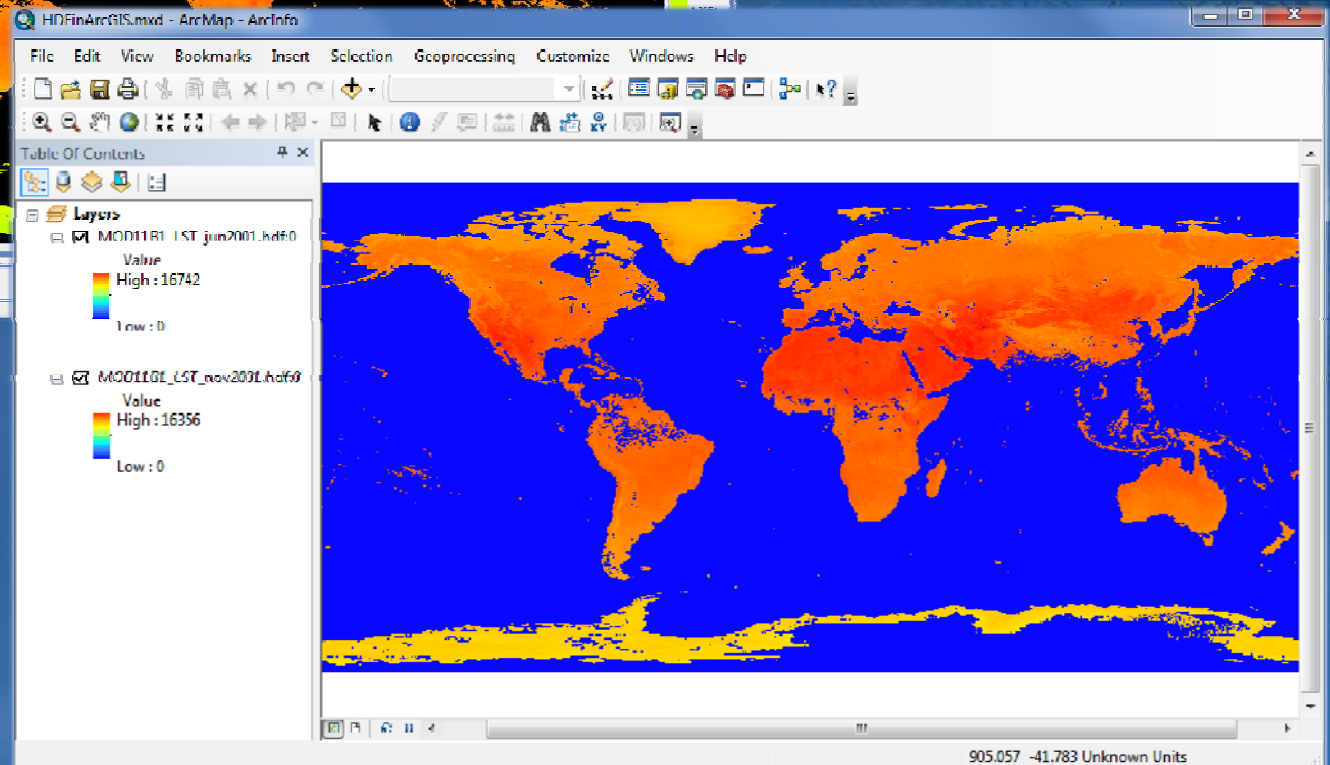
905.057 41.783 Unknown Units

# Displaying MODIS LST Data

HDFView



ArcGIS



# HDF4 and HDF5 Support in ArcGIS

The screenshot shows the ArcGIS 10 Help window with the 'Supported raster dataset file formats' section selected in the Contents pane. The main content area displays a table of supported raster formats. The 'Hierarchical Data Format (HDF) 4' and 'Hierarchical Data Format (HDF) 5' entries are highlighted with a red box.

Golden Software Grid (.grd)	There are 3 types of Golden Software Grids that are supported: Golden Software ASCII GRID (GSAG), Golden Software Binary Grid (GSBG), and Golden Software Surfer 7 Binary Grid (GS7GB).	Single file—extension *.grd	Read-only (Write—developer only for GSAG and GSBG)
Hierarchical Data Format (HDF) 4	A self-defining file format used for storing arrays of multidimensional data.	Single file—extension *.hdf	Read-only (Write—developer only)
Hierarchical Data Format (HDF) 5	The next generation standard for HDF.	Single file—Possible file extensions are *.h5, and *.hdf5	Read-only (Write—developer only)
IDRISI Raster Format (RST)	File format native to <a href="#">IDRISI</a> .	Multiple files Raw image—extension *.rst Descriptor—extension *.rdc Color map—extension *.smp Georeference file—extension *.ref	Read-only (Write—developer only)
Intergraph raster files: CIT—Binary	Intergraph's proprietary format for 16-bit imagery	Multiple files Binary imagery—	Read-only

<http://help.arcgis.com/en/arcgisdesktop/10.0/help/>

# What is NetCDF?

- **NetCDF** (**n**etwork **C**ommon **D**ata **F**orm)

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.**

# 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,
```

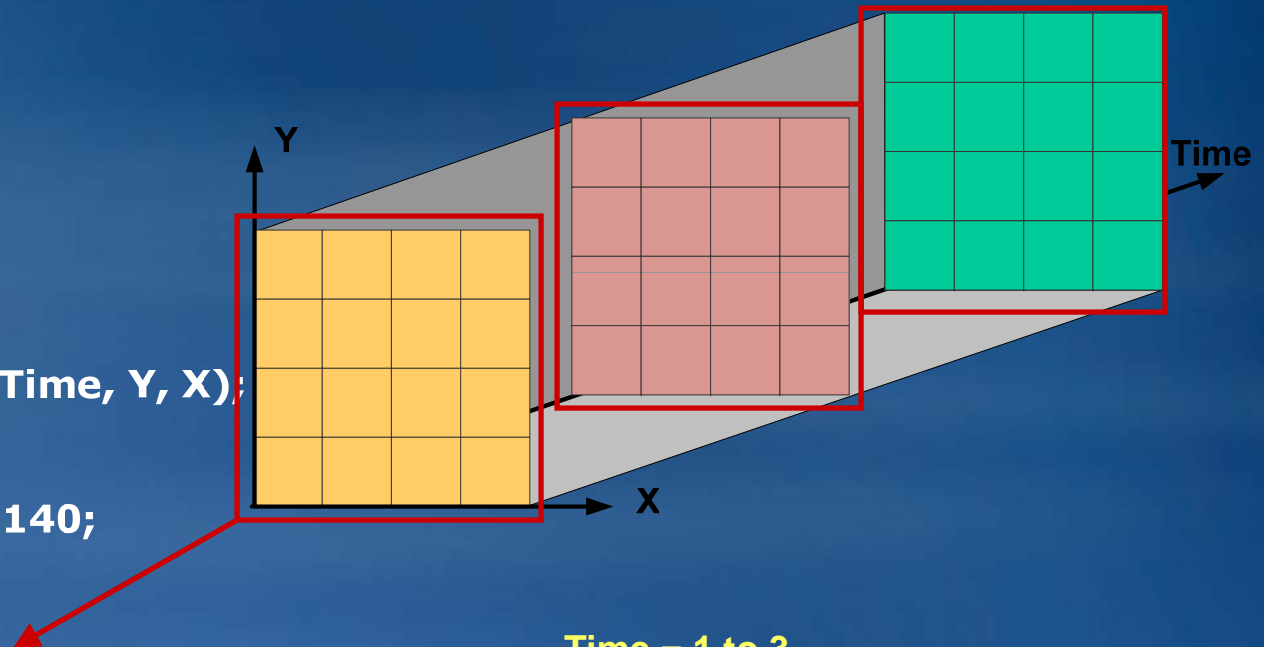
```
  112,212,312,412,122,222,322,422,
```

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

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

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

```
}
```



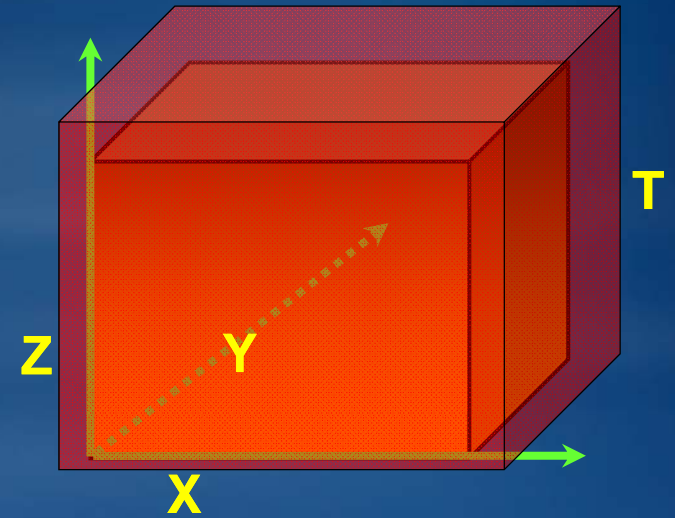
Time = 1 to 3

Y = 1 to 4

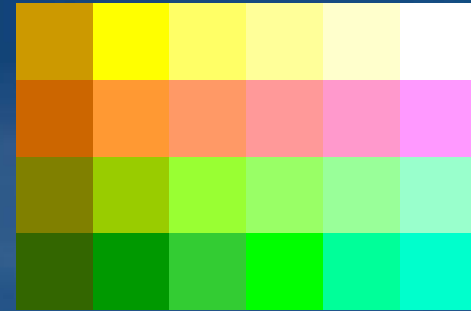
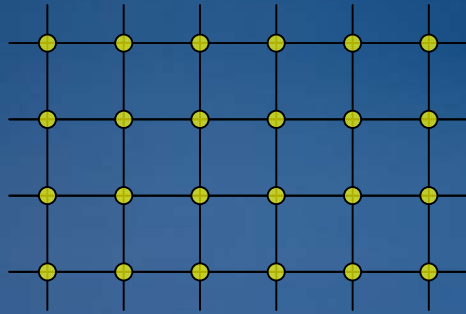
X = 1 to 4

# NetCDF Support in ArcGIS

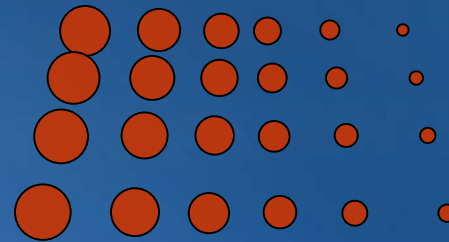
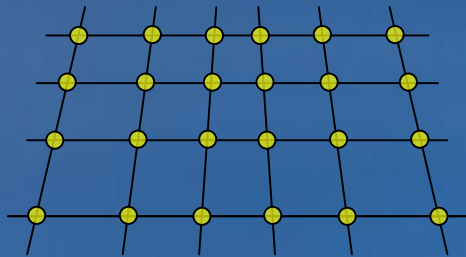
- ArcGIS reads/writes **netCDF** since version 9.2
- An array based data structure for storing multidimensional data.
- N-dimensional coordinates systems
  - X, Y, Z, time, and other dimensions
- Variables – support for multiple variables
  - Temperature, humidity, pressure, salinity, etc
- Geometry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



# Gridded Data



Regular Grid

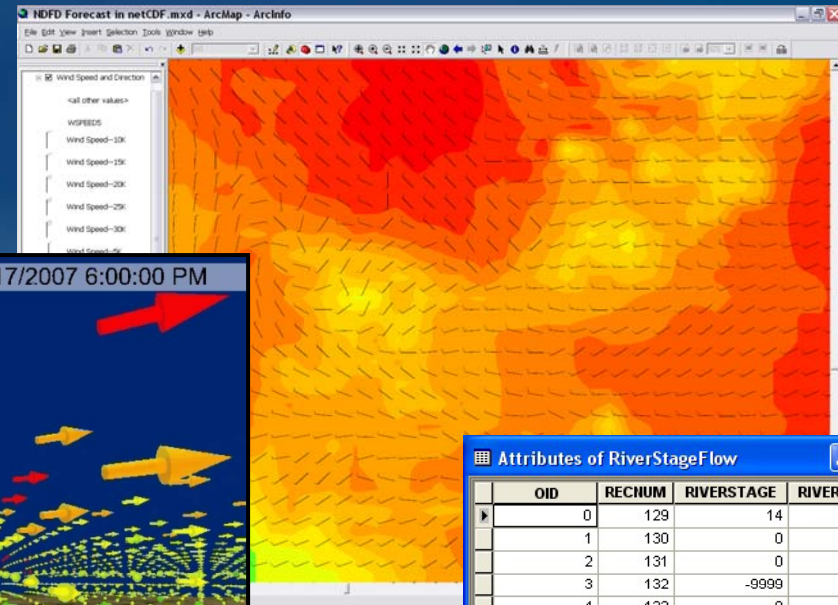


Irregular Grid



# Ingesting netCDF data in ArcGIS

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



- 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



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

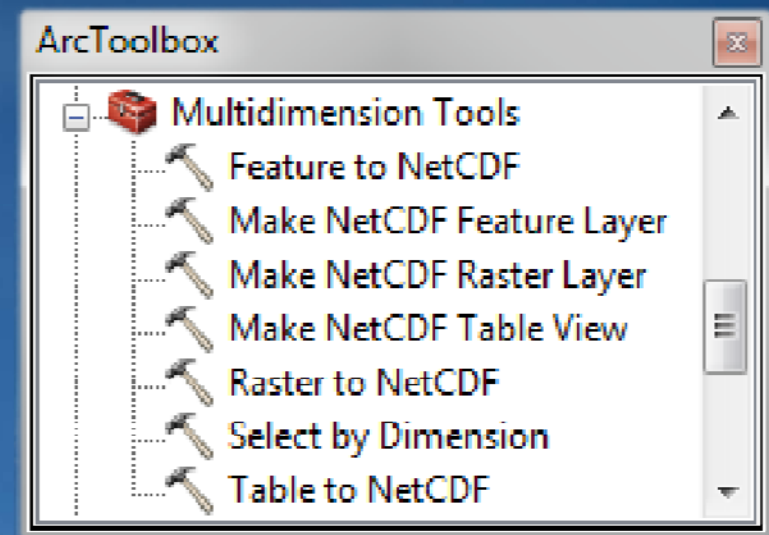
# NetCDF Tools

## Toolbox: Multidimension Tools

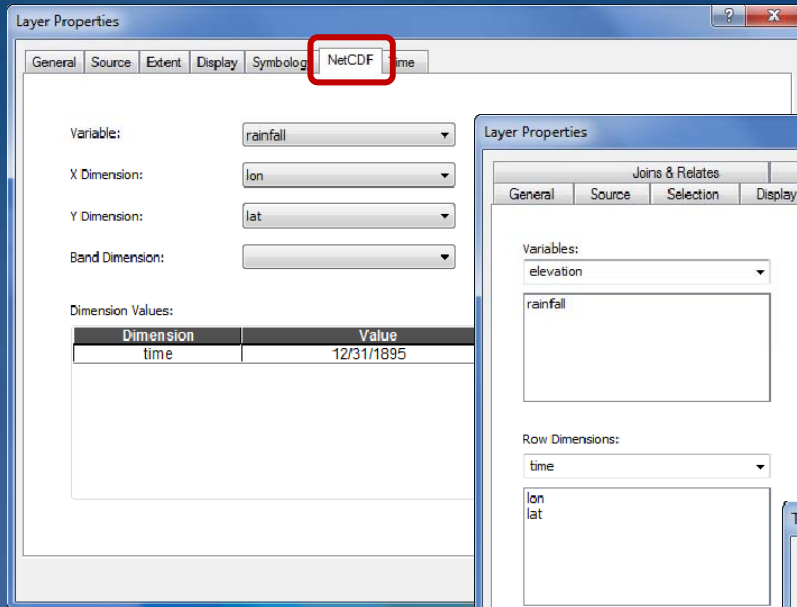
- Make NetCDF Raster Layer
- Make NetCDF Feature Layer
- Make NetCDF Table View

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

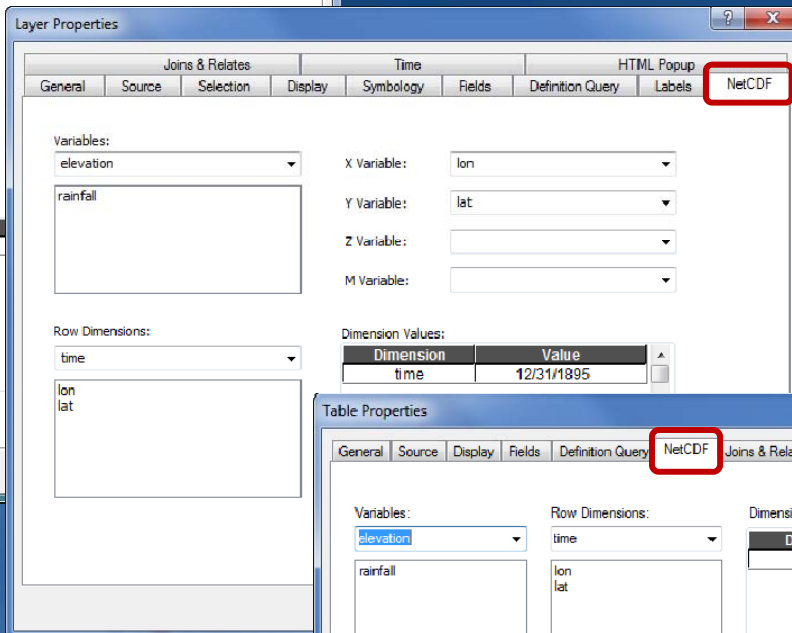
- Select by Dimension



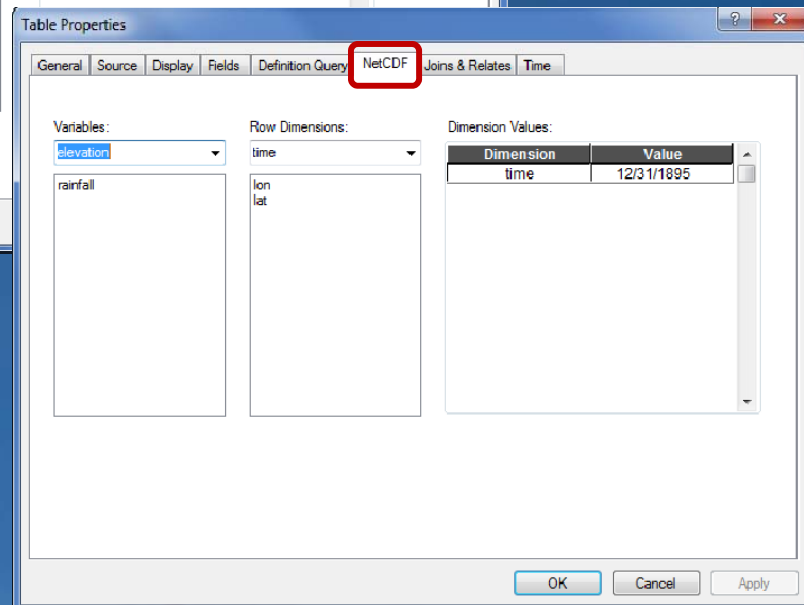
# NetCDF Layer/Table Properties



Raster

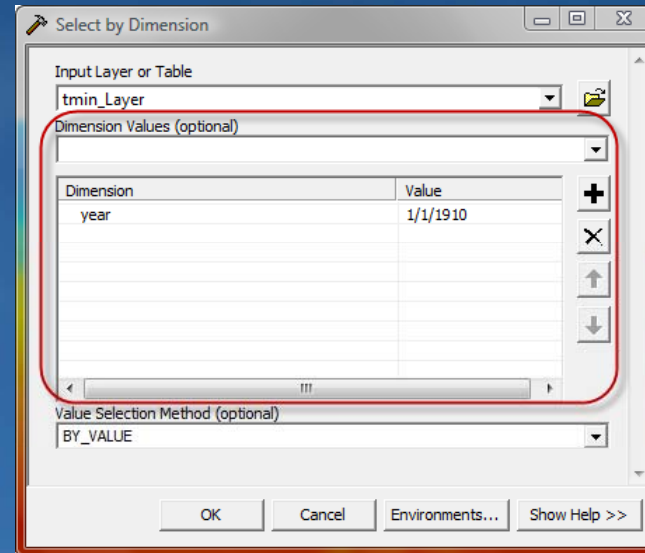
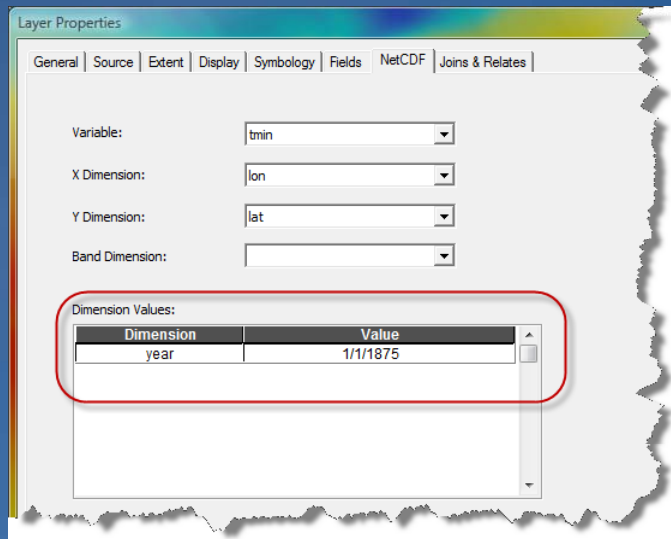
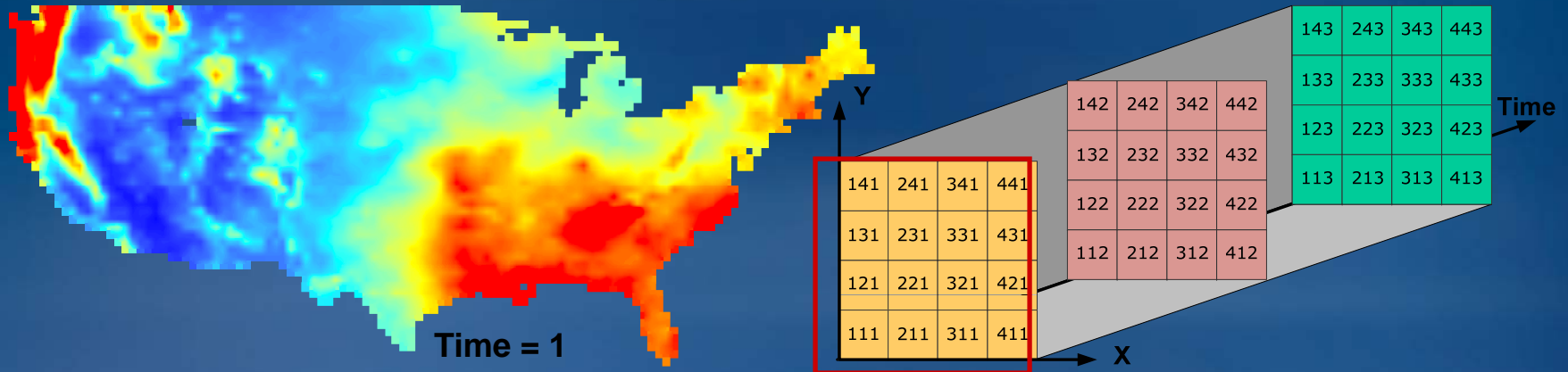


Feature



Table

# Changing Time Slice



# 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.)

# Help on netCDF

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 way to share data

Learn more about where netCDF data is used

Related Topics

- Essential netCDF vocabulary
- Fundamentals of netCDF data storage
- How ArcGIS represent 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

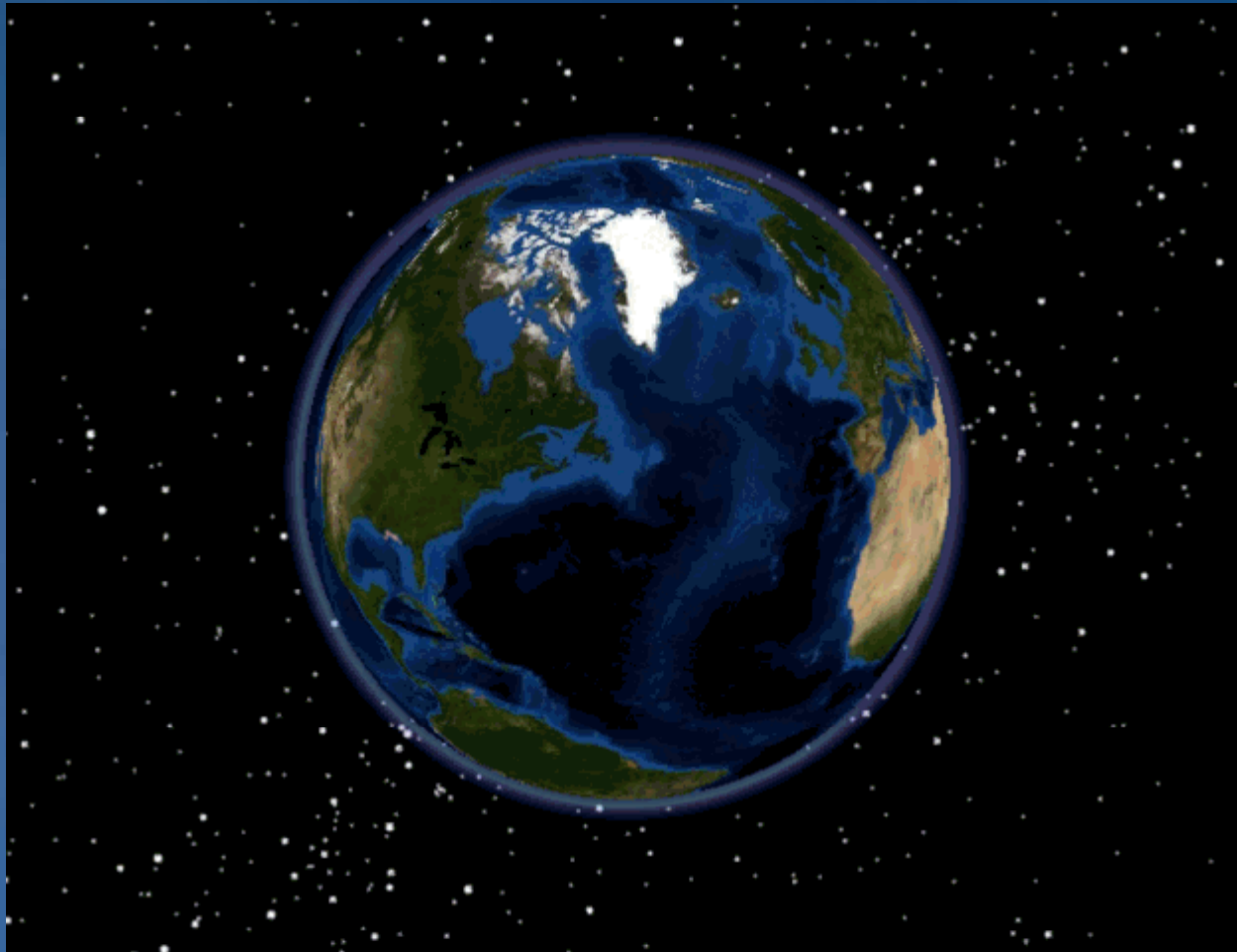
Related Topics

# Time in ArcGIS





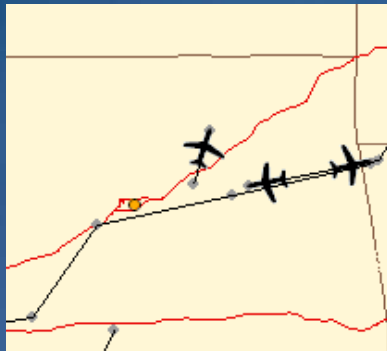
## Why visualize data through time?



# Temporal GIS Patterns

## Dynamic

something that moves



- Planes
- Vehicles
- Animals
- Satellites
- Storms

## Discrete

something that  
“just happens”



- Crimes
- Lightning
- Accidents

## Stationary

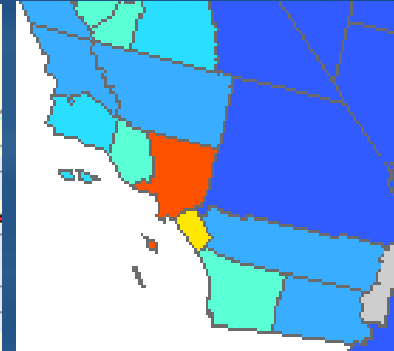
stands still but  
records changes



- Weather Stations
- Traffic Sensors

## Change

change or growth



- Population
- Distribution
- Fire Perimeter

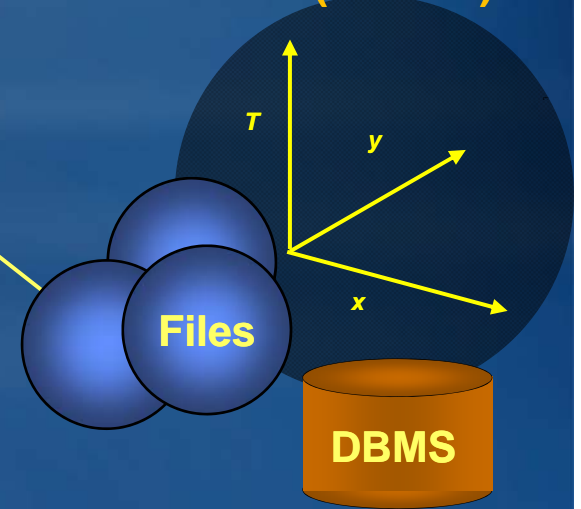
# GIS Integration of Time

*New Ways to Manage, Visualize & Analyze Geography*

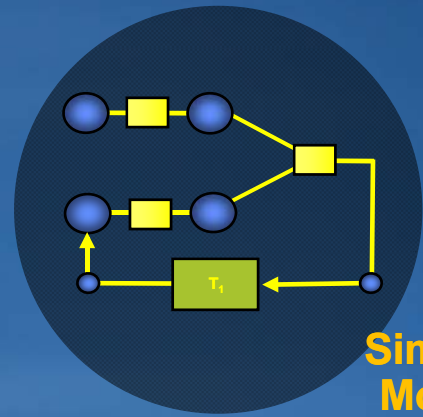
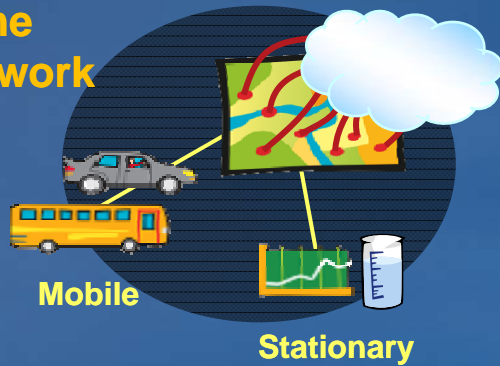
Visualize Change



Multi Dimensional Data (netCDF)



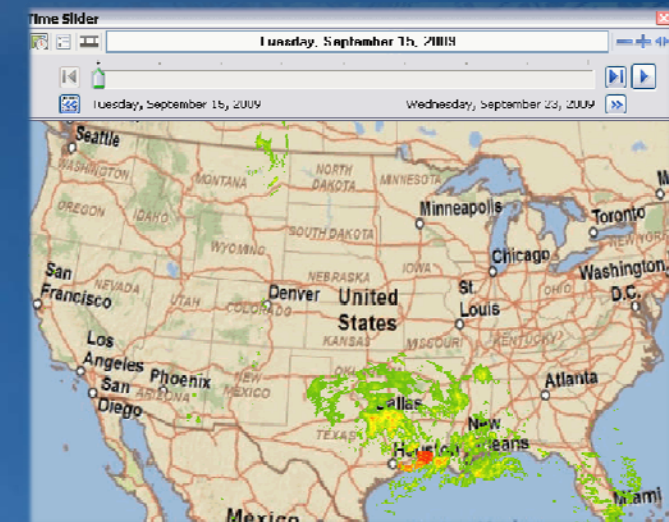
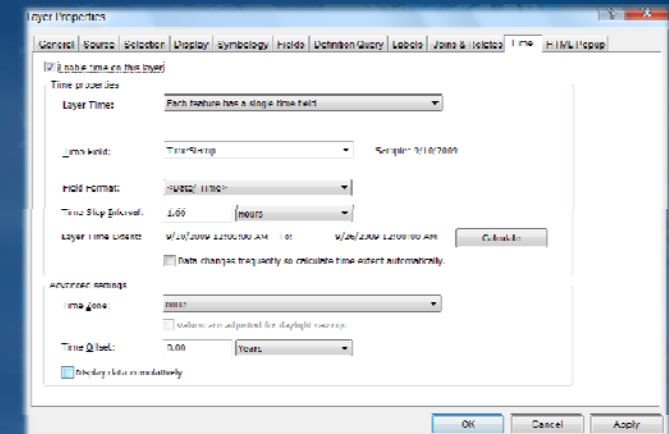
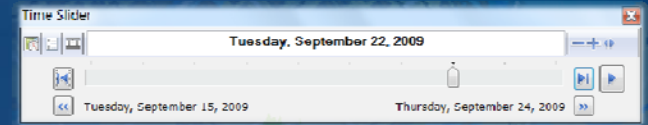
Real Time Sensor Network



Simulation Modeling

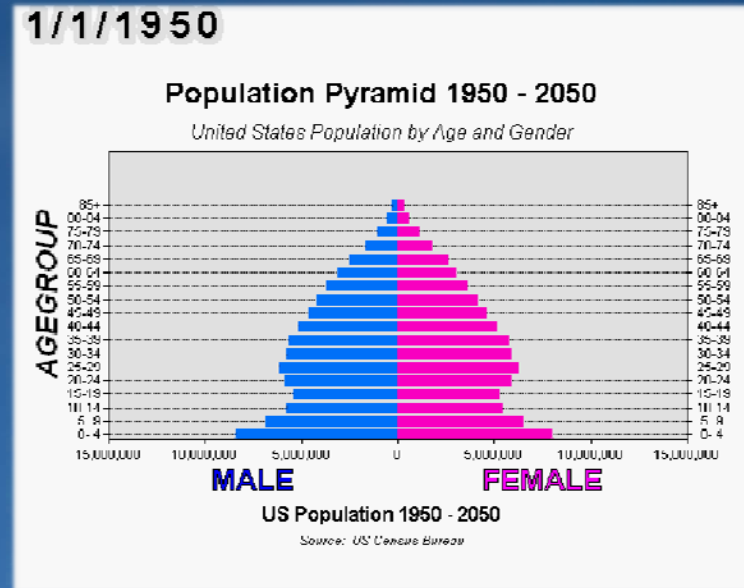
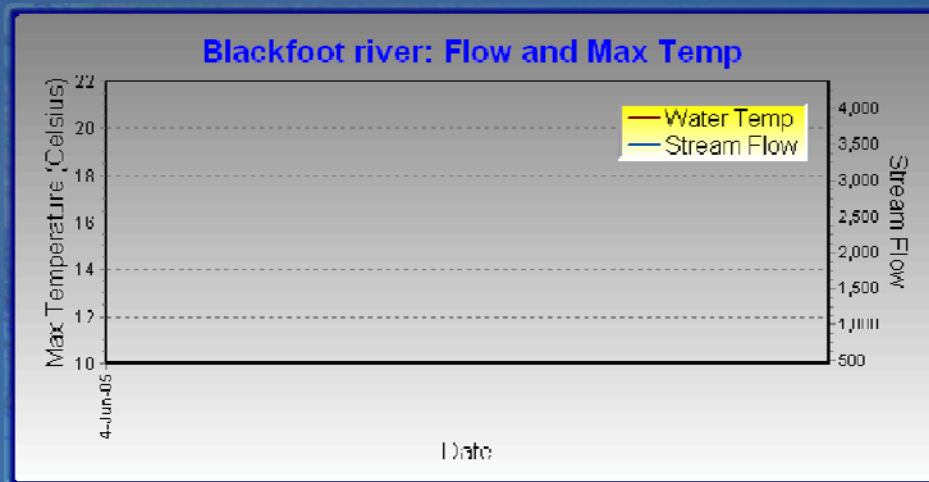
# Time is now built-in to ArcGIS

- Simple Temporal Mapping
- Unified experience for Time
  - Configure time properties on the layer
  - Use Time Slider to visualize temporal data
- Share temporal visualization
  - Time-enabled Map Services
  - Export videos or images
  - Generate temporal map books using ArcPy scripting
  - Layer and map packages

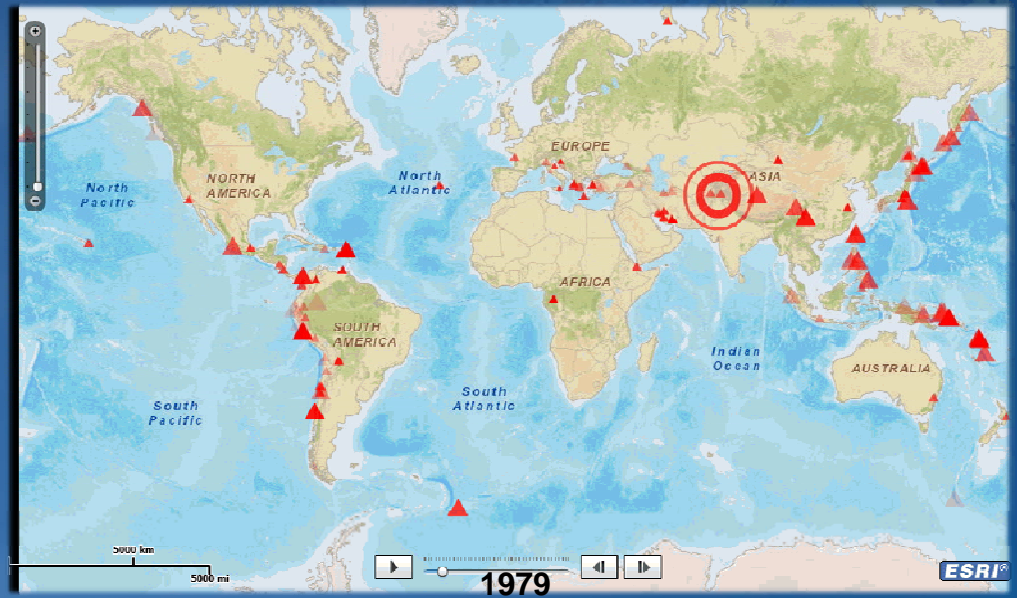
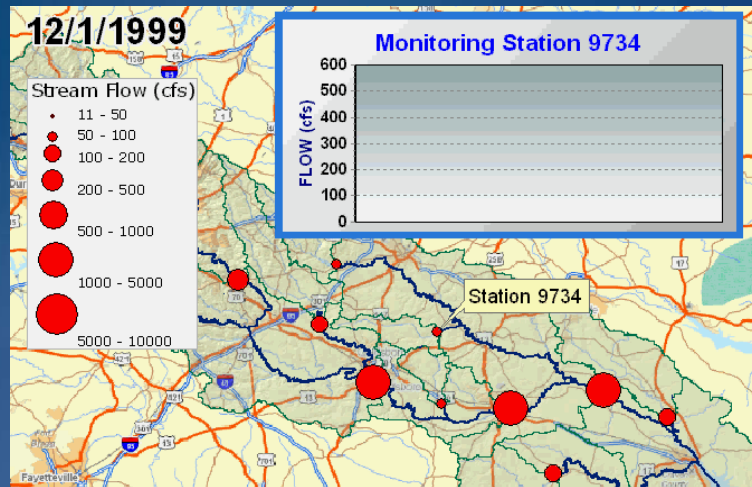


# Visualizing temporal data using graphs

- 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



# Animation examples



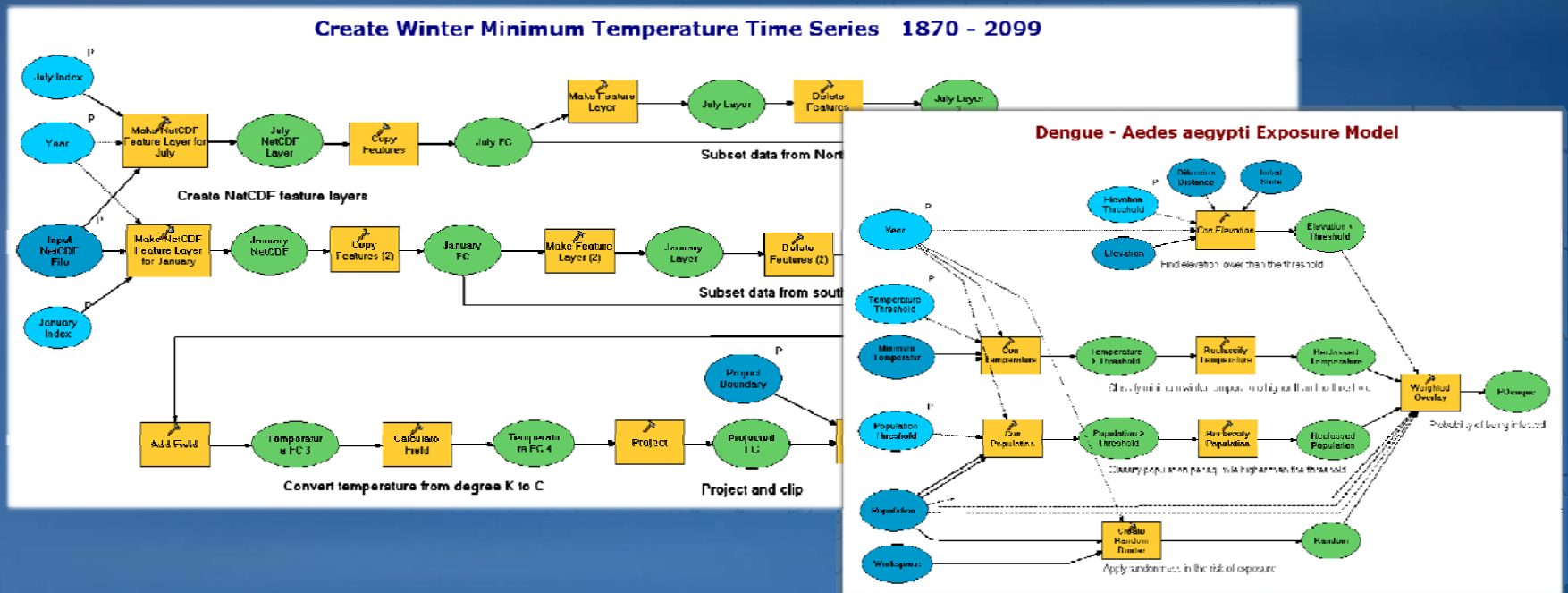


# Performing Analysis



# Spatial and Temporal Analysis

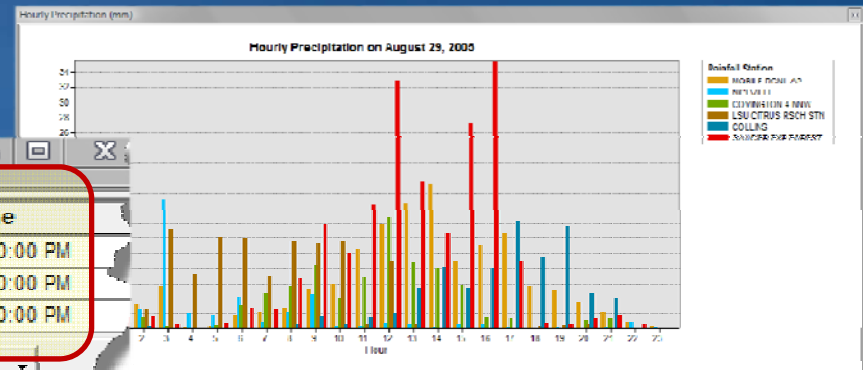
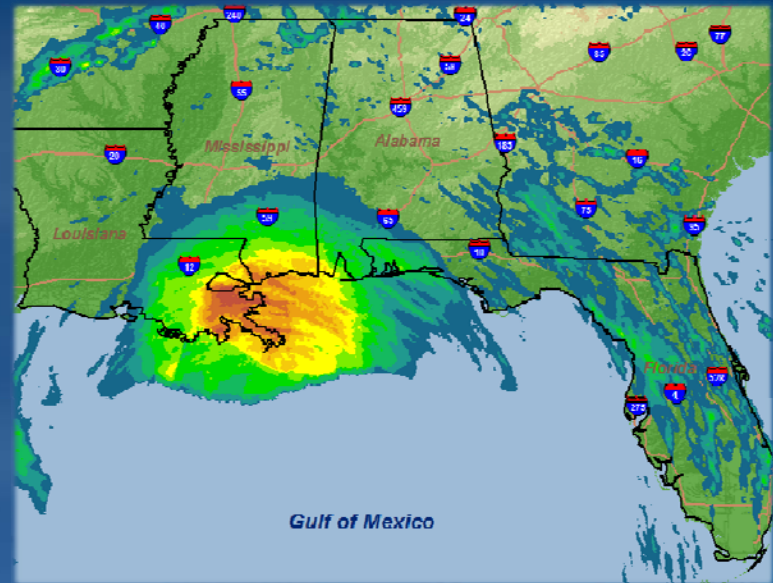
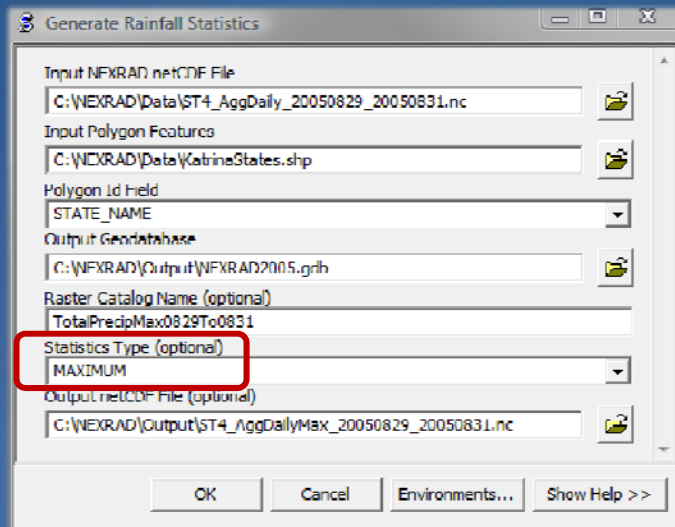
- Several hundreds analytical tools available for raster, features, and table
- Temporal Modeling
  - Looping and iteration in ModelBuilder and Python





# Generate Rainfall Statistics

- Calculates specified statistics for all time steps
- Outputs a raster catalog
- Optionally outputs a netCDF file



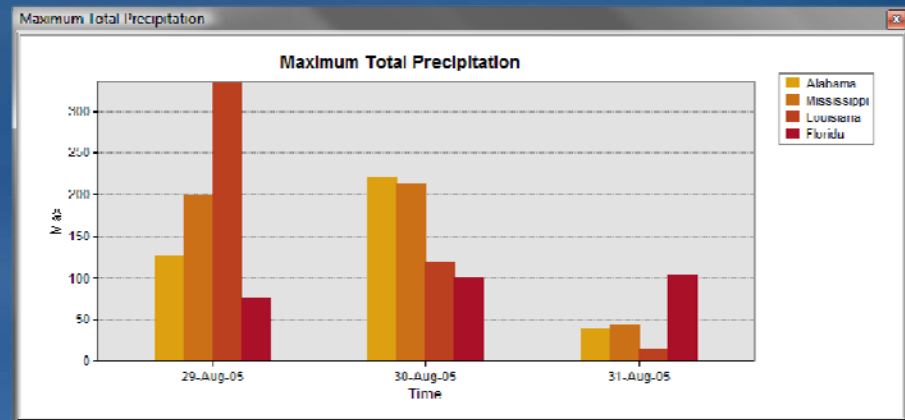
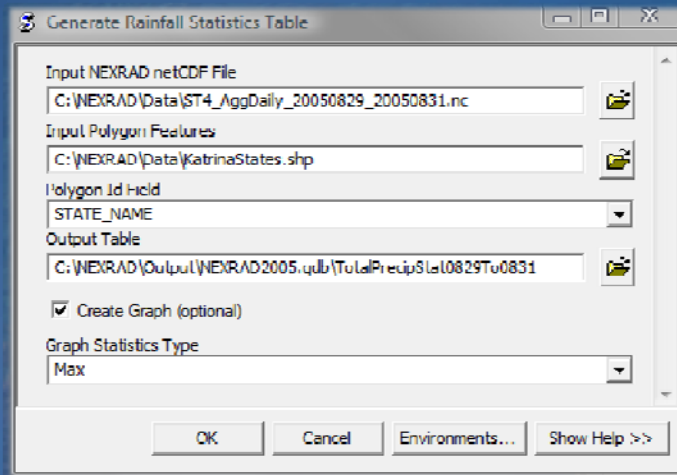
ax0829To0831

Raster	Name	Shape_Length	Shape_Area	TimeIndex	time
<Raster>	tpzs0	19071.052	22404883.190591	0	8/29/2005 12:00:00 PM
<Raster>	tpzs1	19071.052	22404883.190591	1	8/30/2005 12:00:00 PM
<Raster>	tpzs2	19071.052	22404883.190591	2	8/31/2005 12:00:00 PM

Show: All Selected Records (9 out of 3 Selected) Options

# Generate Rainfall Statistics Table

- Calculates statistics for all time steps
- Outputs a table
- Optionally creates a graph



TotalPrecipStat0829To0831

	STATE_NAME	ZONE_CODE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM	rmeIndex	time
1	Alabama	1	8633	195849.7	0	126	126	4.441654	11.310238	38344.801	0	8/29/2005 12:00:00 PM
2	Mississippi	2	7973	180875.6	0	198.80001	198.80001	12.567554	27.046635	100201	0	8/29/2005 12:00:00 PM
3	Louisiana	3	7921	179697.14	0	335.5	335.5	24.223646	48.256098	191875.5	0	8/29/2005 12:00:00 PM
4	Florida	4	10123	229652.09	0	75.059998	75.099998	7.08211	9.422755	71692.203	0	8/29/2005 12:00:00 PM
5	Alabama	1	8633	195849.7	4	220.40001	216.40001	43.57959	28.550621	376222.59	1	8/30/2005 12:00:00 PM
6	Mississippi	2	4211	95531.461	0.6	212.60001	212	87.248848	28.006405	367404.91	1	8/30/2005 12:00:00 PM
7	Louisiana	3	5072	115064.25	0	119.9	119.9	5.48871	10.177142	27737.301	1	8/30/2005 12:00:00 PM
8	Florida	4	10123	229652.09	0	99.300003	99.300003	7.511341	13.429757	78037.305	1	8/30/2005 12:00:00 PM
9	Alabama	1	8633	195849.7	0	39.100002	39.100002	1.2909	3.457737	11213.4	2	8/31/2005 12:00:00 PM
10	Mississippi	2	4211	95531.461	0	43	43	0.486037	2.864363	2046.7001	2	8/31/2005 12:00:00 PM
11	Louisiana	3	5072	115064.25	0	14.1	14.1	0.076636	0.612823	388.70001	2	8/31/2005 12:00:00 PM
12	Florida	4	10123	229652.09	0	103.4	103.4	4.583509	7.578799	46196.402	2	8/31/2005 12:00:00 PM

Record: 14 | Show: All Selected | Records (0 out of 12 Selected) | Options

Demo



# Use Cases and Applications

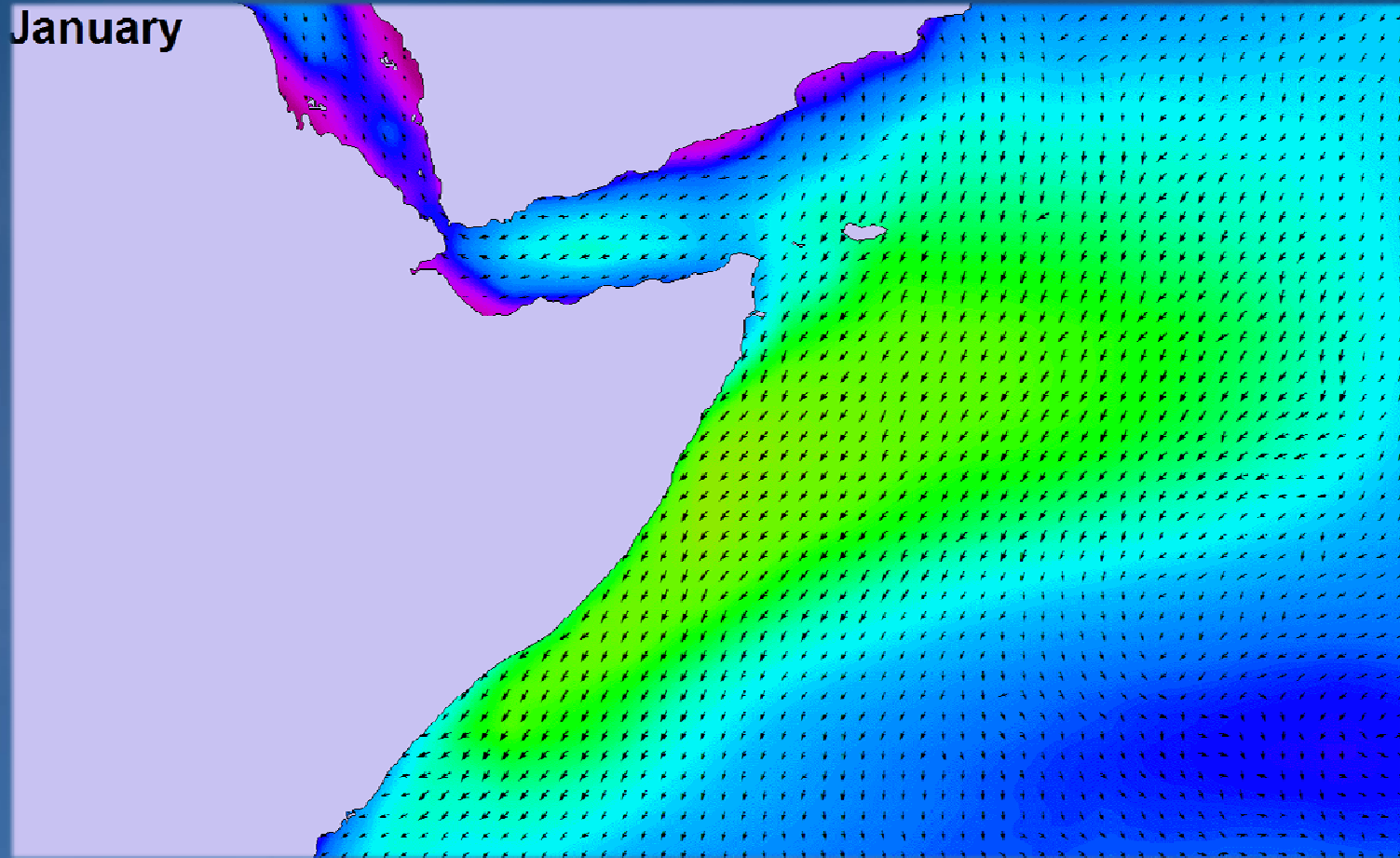
- Hydrography and METOC Branch, Royal Australian Navy
- Applied Science Associated, Inc.
- The Nature Conservancy
- The University of Washington
- The University of Southern Mississippi



# Observations and Model Forecasts

- **Near real-time observations**
  - **Weather satellite imagery**
  - **Sea Surface Temperature**
  - **Significant Wave Height (altimeter)**
  - **Ocean Winds**
  - **Moisture and Precipitation**
- **Numerical model forecasts**
  - **Fixed domain Global, Regional, Tropical and Local atmospheric models (ACCESS)**
  - **Fixed domain Global, Regional, and Local wave models (WaveWatch 3)**
  - **Global Ocean Model (BLUElink)**
  - **Relocatable high-resolution atmospheric and ocean models**

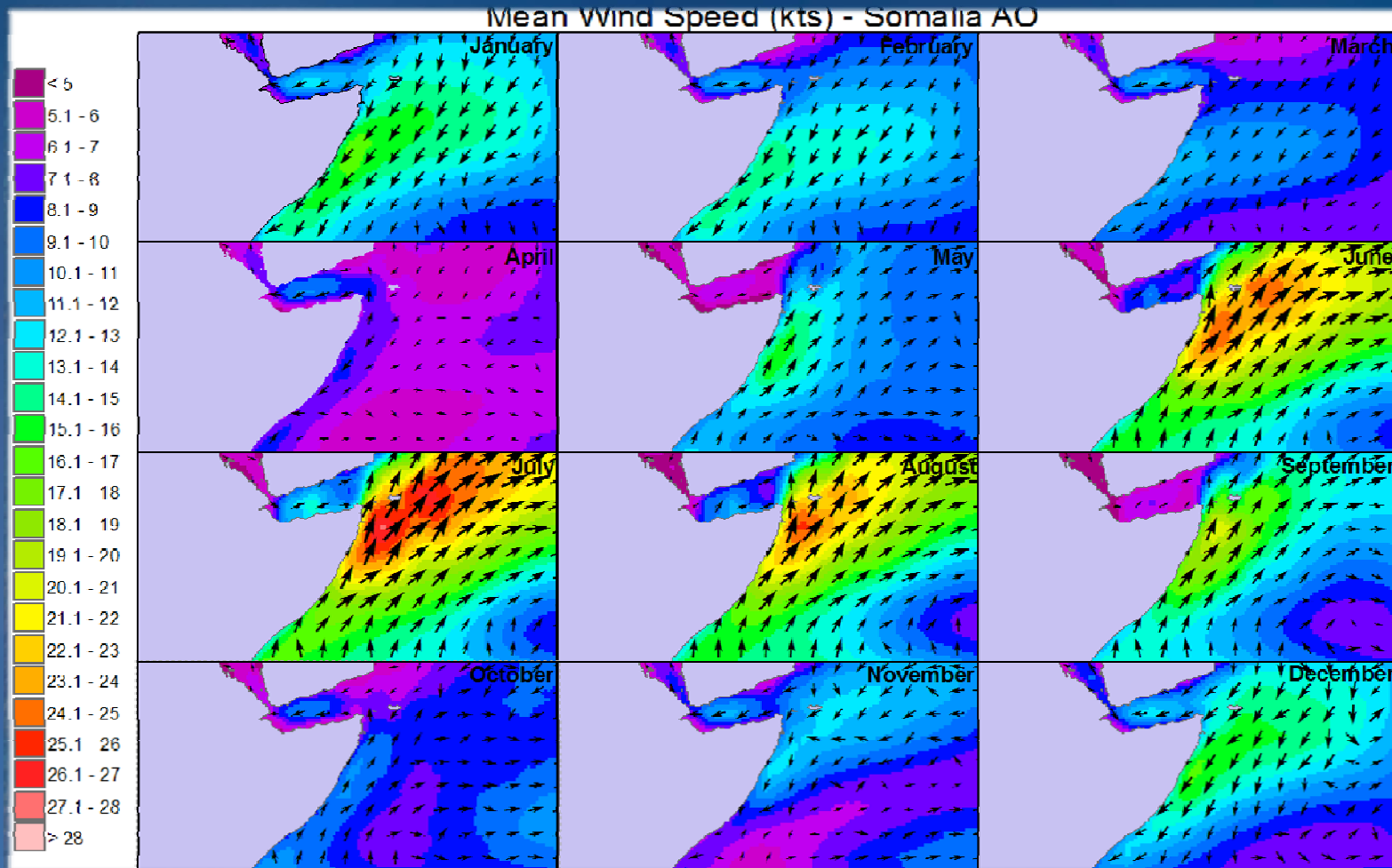
# Climatology – CCMP Winds



Source: Hydrography and METOC Branch, Royal Australian Navy.

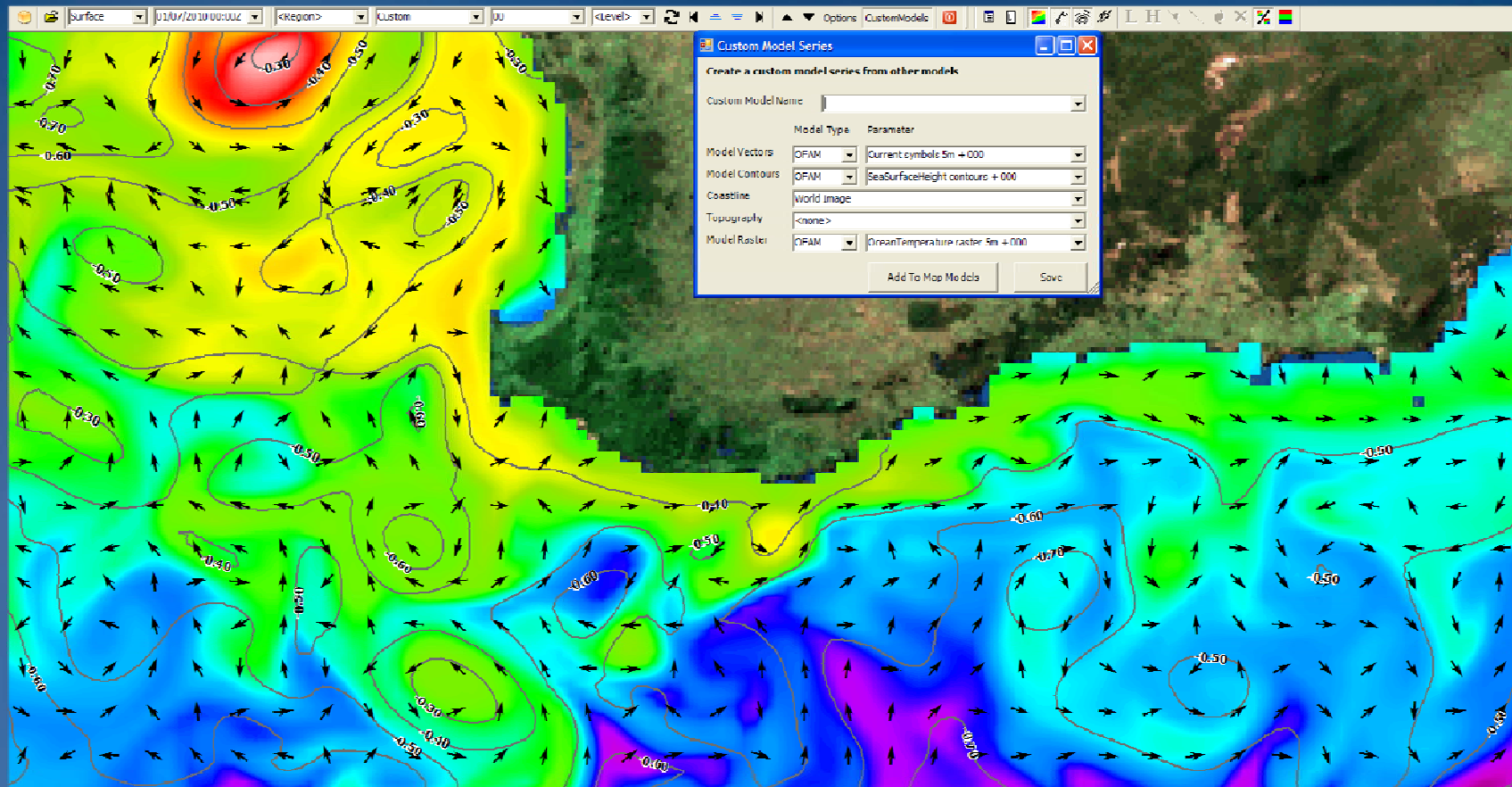


# Climatology – CCMP Winds



Source: Hydrography and METOC Branch, Royal Australian Navy.

# Ocean Model Forecast – Custom Display



Source: Hydrography and METOC Branch, Royal Australian Navy.



# Web Services - GHRSSST

hydro metoc

Minister | Navy | Army | Air Force | Department

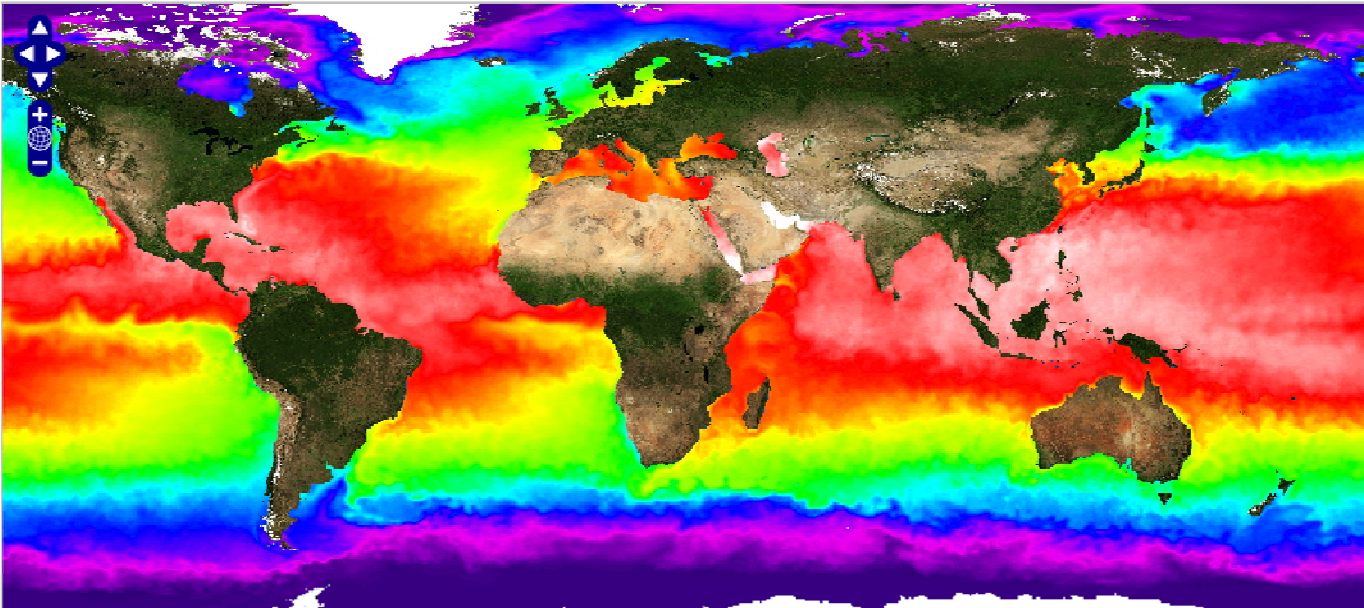
Navy METOC

Home About Us Products & Services Defence Only

Public Unclassified

Met Office UK Met Office OSTIA SST Analysis

Holding SHIFT and drawing a rectangle will zoom to area

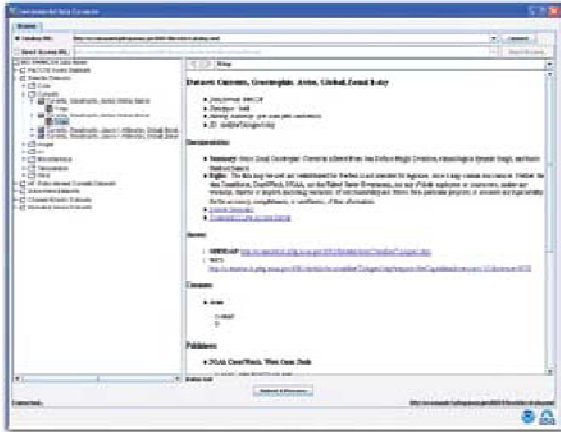


Produced by Navy Hydrography and METOC Branch  
Data Source: UKMO OSTIA Analysis, valid: 12 Jul 2010

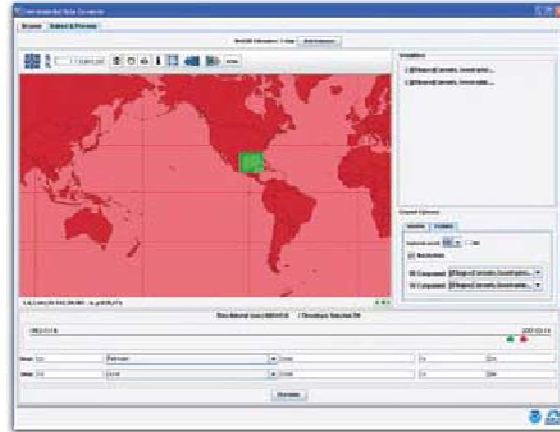
Scale = 1 : 111M  
lon: -99.242, lat: 61.172

Source: Hydrography and METOC Branch, Royal Australian Navy.

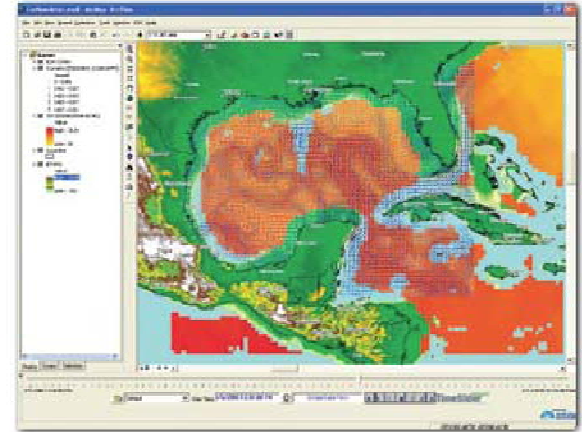
# Environmental Data Connector (EDC)



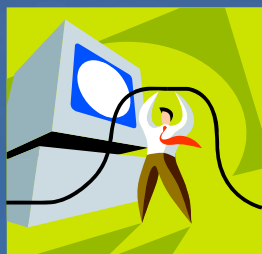
EDC Java-based interface for dataset browsing.



EDC selection of variables and spatial and temporal subsetting.



ArcGIS display showing data retrieved using EDC. All datasets shown are from OPeNDAP sources.



THREDDS



DAP



Java App,  
Unidata



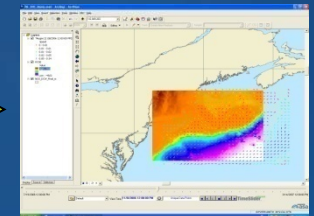
XML  
NetCDF



ArcGIS  
Extension

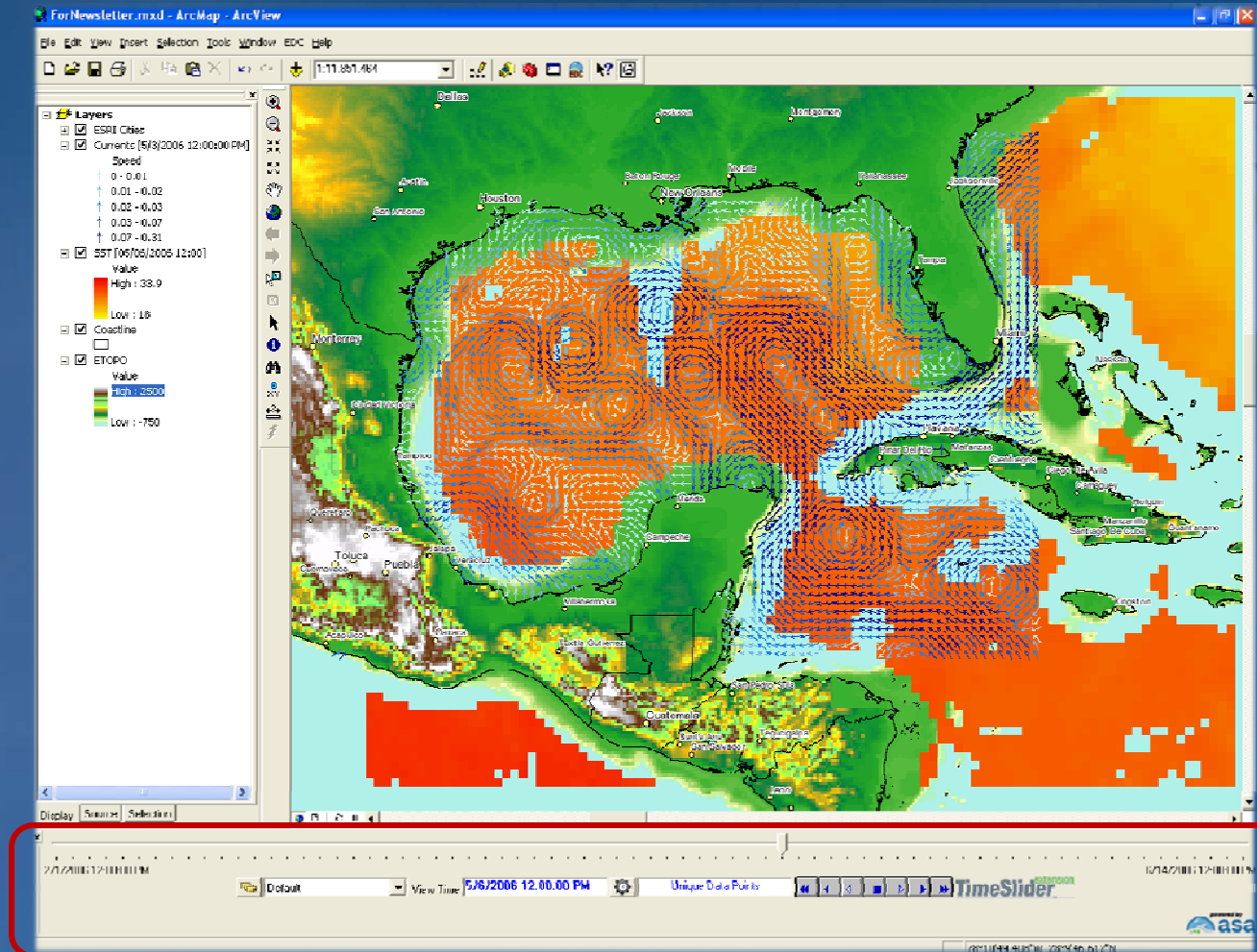


Features  
Rasters



# EDC Screen and Time Slider Toolbar

Synchronize and animate time-varying data in

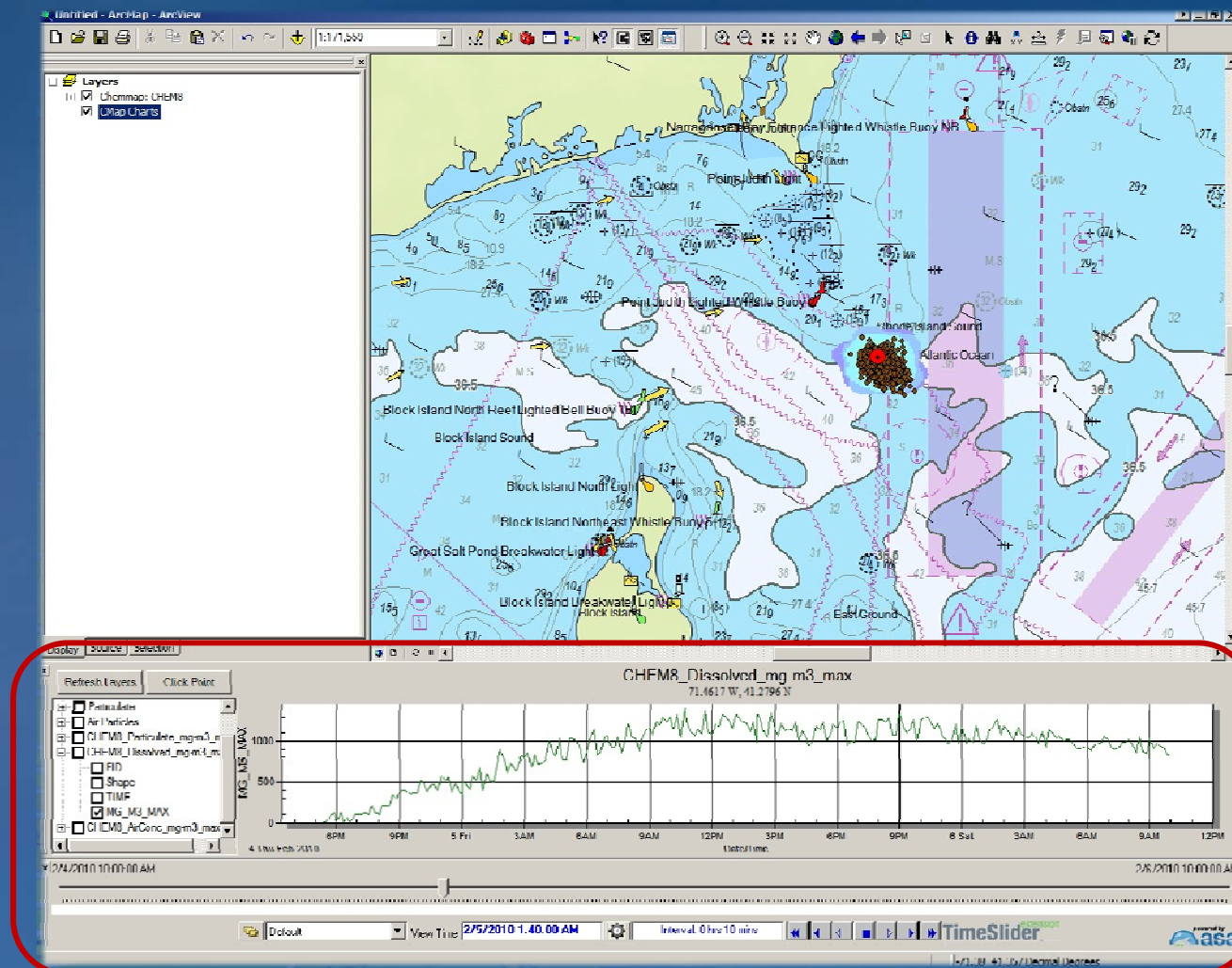


<http://www.pfeg.noaa.gov/products/EDC/>

<http://www.asascience.com/TimeSlider/index.htm>

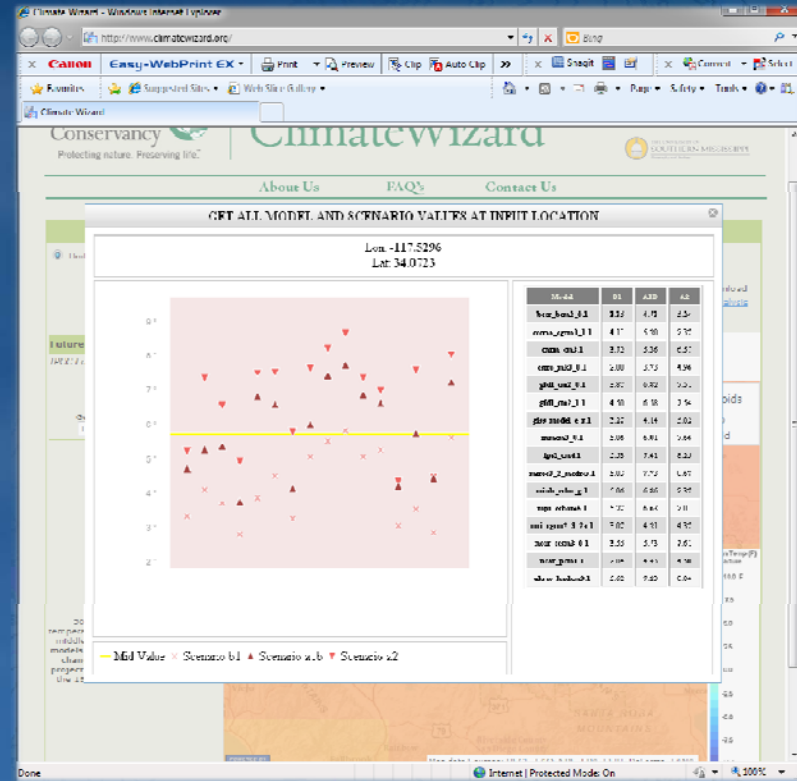
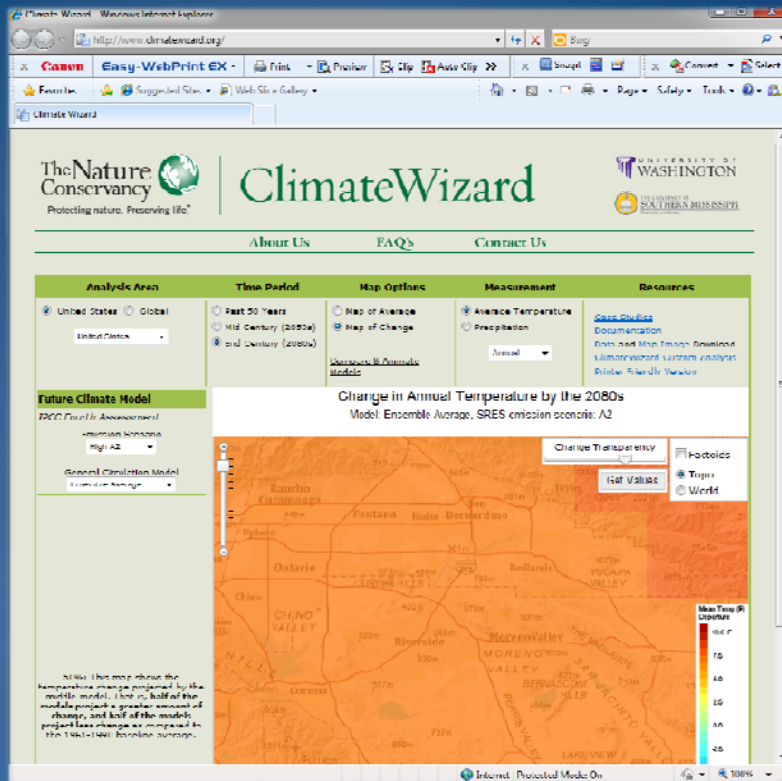
Source: Applied Science Associated, Inc.

# Time Series Graphs





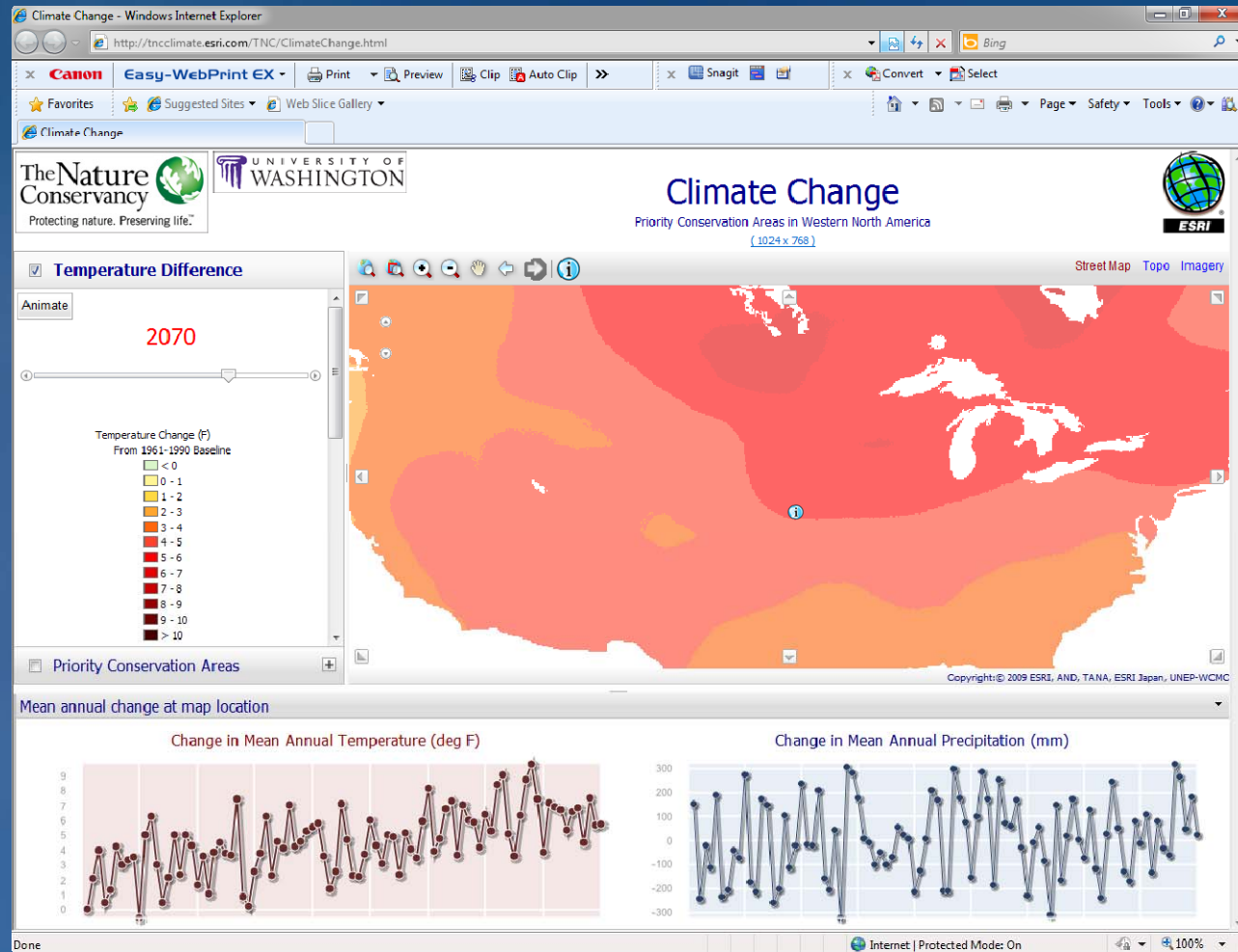
# Climate Wizard



<http://www.climatewizard.org/>

Developers: The Nature Conservancy, The University of Washington, and The University of Southern Mississippi

# Climate Change



<http://tncclimate.esri.com/TNC/ClimateChange.html>

Developers: The Nature Conservancy, The University of Washington, and ESRI

# Script Tools





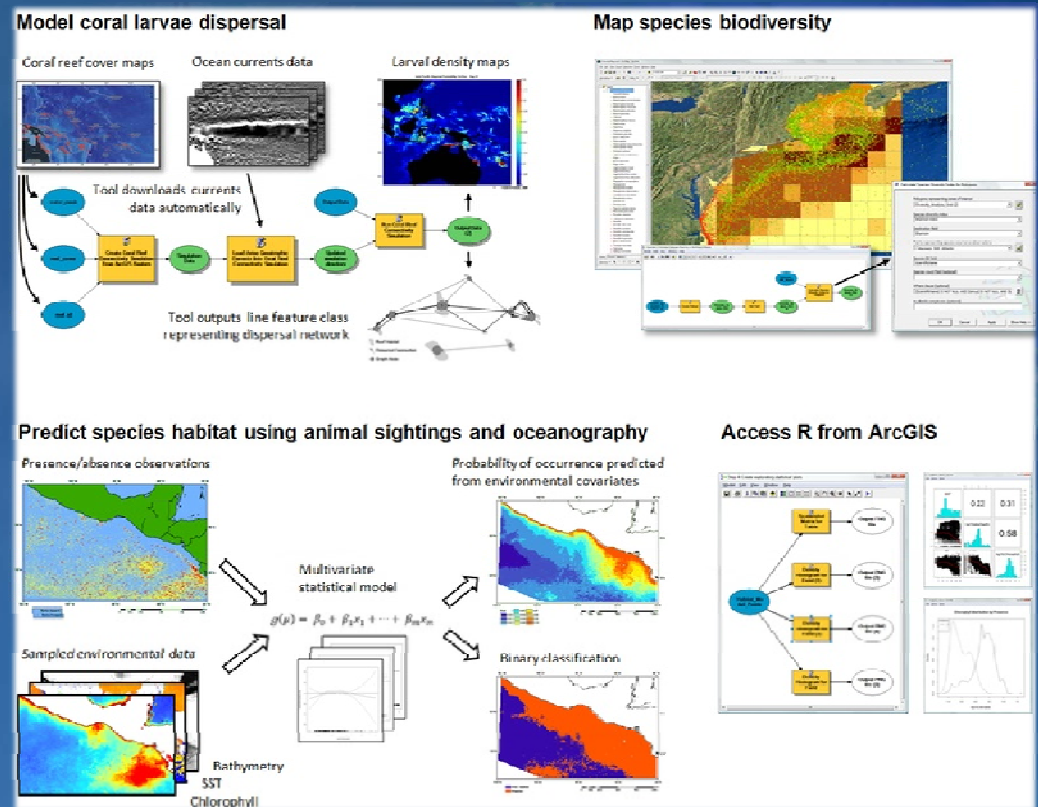
# Community Developed Tools

- Geoprocessing Resource Center  
<http://resources.arcgis.com/geoprocessing/>

- Marine Geospatial Ecology Tools

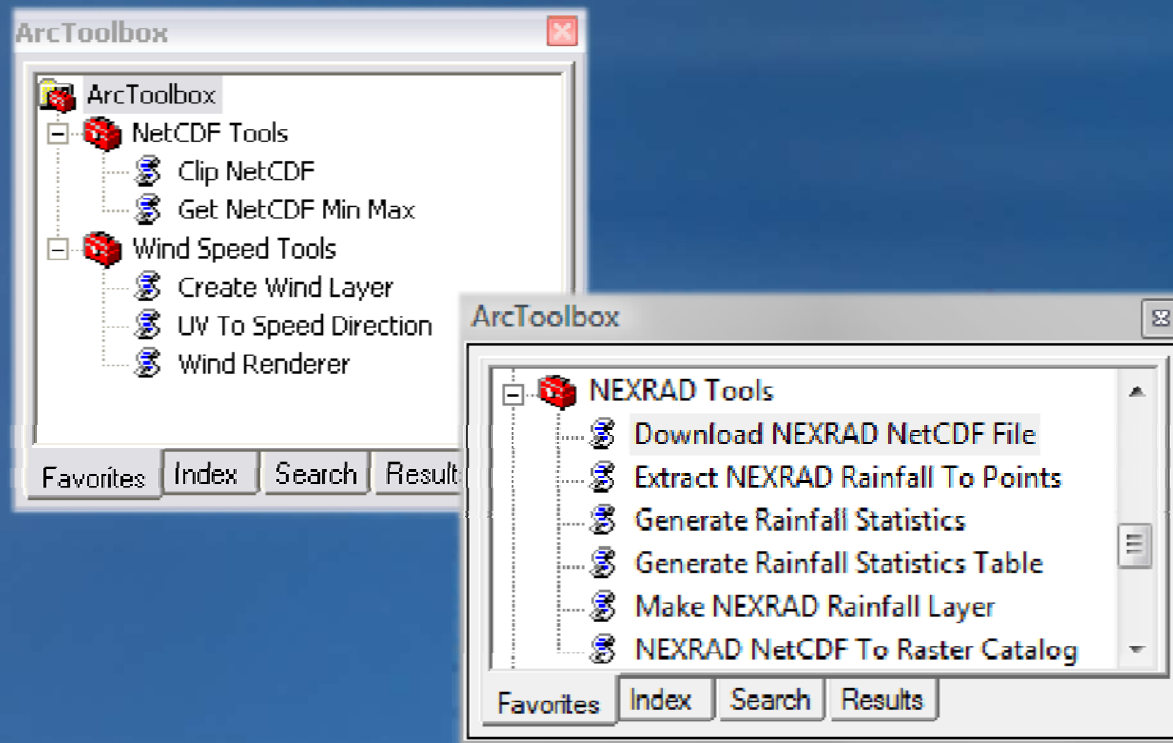
- Developed at Duke Univ.
- Over 180 tools for import management, and analysis of marine data

- Australian Navy tools (not publicly available)



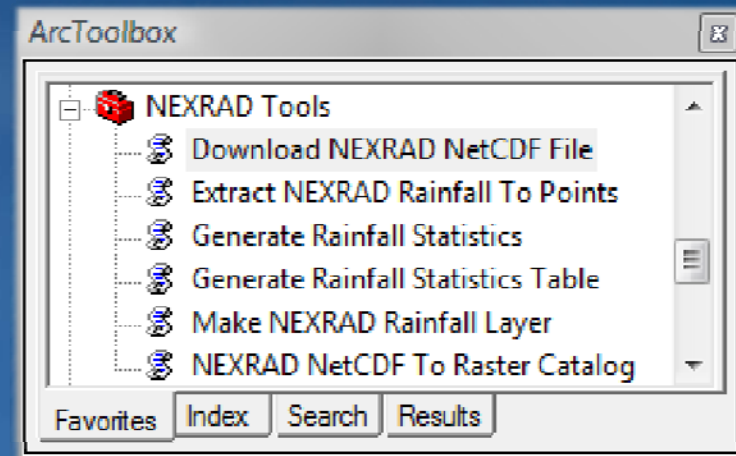
# Script Tools of interest

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



# NEXRAD Geoprocessing Tools

- Currently 6 geoprocessing script tools
- Designed to work with NEXRAD netCDF file
- Can be easily modified for other datasets
- Customized tools for various workflows
- Simplify repetitive work
- Automate GIS processes



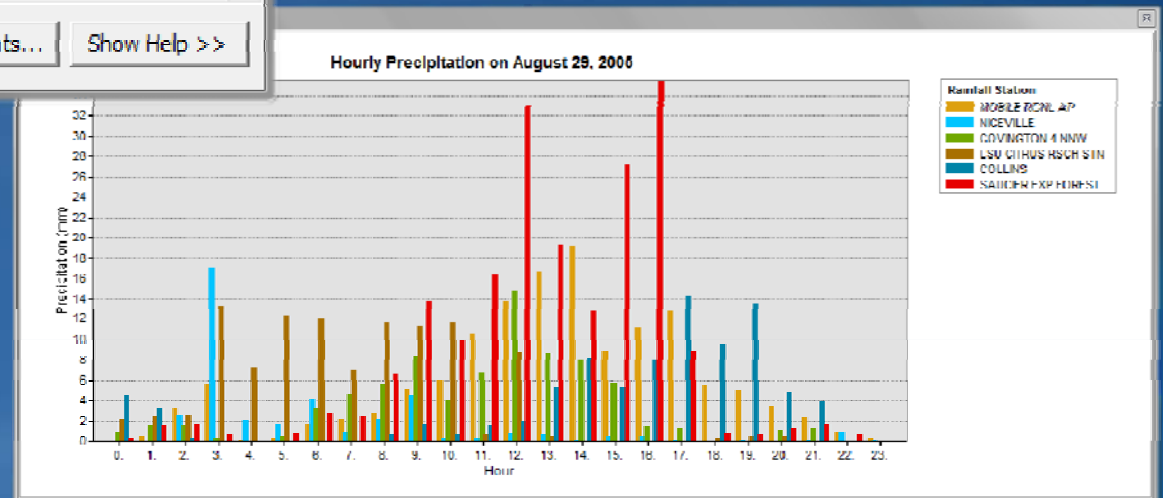
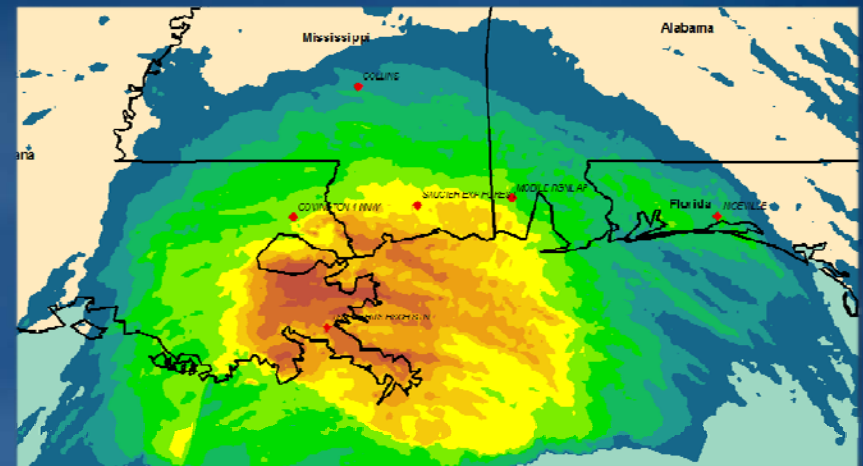
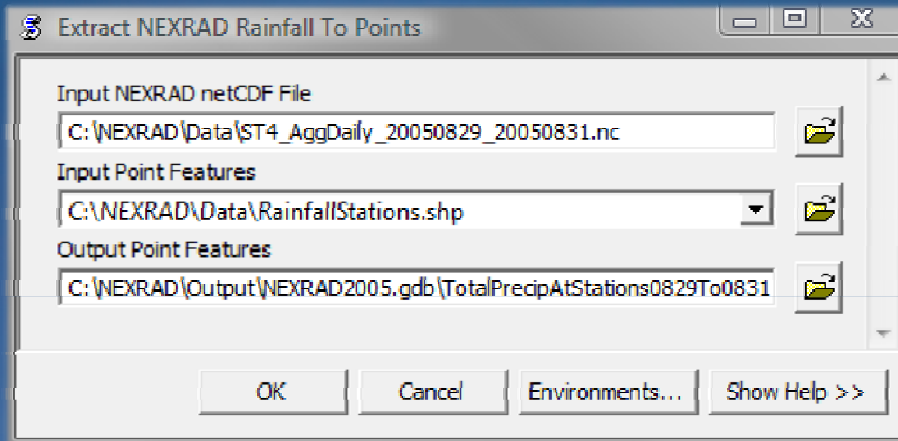
# Download NEXRAD NetCDF File

- Downloads netCDF file from the THREDDS server

The image displays a web browser window showing a THREDDS catalog and a local application window for downloading a NetCDF file. The browser window is titled "Catalog" and shows a list of datasets under the URL "http://www.ncdc.noaa.gov". The "Dataset" list includes "StIV" and "hour-agg-test/". The "Subset Service for Grids" section shows a selected dataset "ST4\_Agg\_2005-TEST.nc" with a time range from "2005-08-29T12:00:00Z" to "2005-08-31T12:00:00Z". The "Choose Spatial Subset" section is set to "All" and "Choose Time Subset" is set to "Time Range" with the same time range. The local application window, titled "Download NEXRAD NetCDF File", has the following fields: "Input NEXRAD netCDF Dataset" (ST4\_Agg\_2005-TEST.nc), "Output netCDF File" (C:\NEXRAD\Output\ST4\_AggDaily\_20050829\_20050831.nc), "URL (optional)" (http://www.ncdc.noaa.gov/thredds/ncss/grid/radar/StIV), "Extent (optional)" (empty), "Start Time (optional)" (2005-08-29T12:00:00Z), and "End Time (optional)" (2005-08-31T12:00:00Z). A yellow arrow points from the "Input NEXRAD netCDF Dataset" field to the "ST4\_Agg\_2005-TEST.nc" entry in the browser catalog. Another yellow arrow points from the "Choose Time Subset" section to the "End Time (optional)" field.

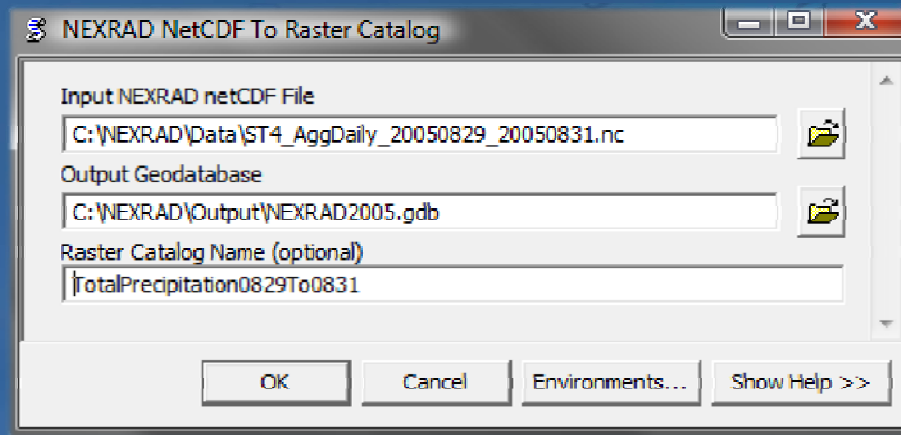
# Extract NEXRAD Rainfall To Points

- Extracts the cell values for all time steps
- Outputs a feature class



# NEXRAD NetCDF To Raster Catalog

- Creates a raster catalog
- Each catalog item corresponds to a time slice in the netCDF file



Attributes of TotalPrecipitation0829TO0831

OBJECTID *	Shape *	Raster	Name	Shape_Length	Shape_Area	TimeIndex	time
1	Polygon	<Raster>	tprecip0	19071.052	22404883.190568	0	8/29/2005 12:00:00 PM
2	Polygon	<Raster>	tprecip1	19071.052	22404883.190568	1	8/30/2005 12:00:00 PM
3	Polygon	<Raster>	tprecip2	19071.052	22404883.190568	2	8/31/2005 12:00:00 PM

Record: 1 Show: All Selected Records (0 out of 3 Selected) Options

# Future Directions



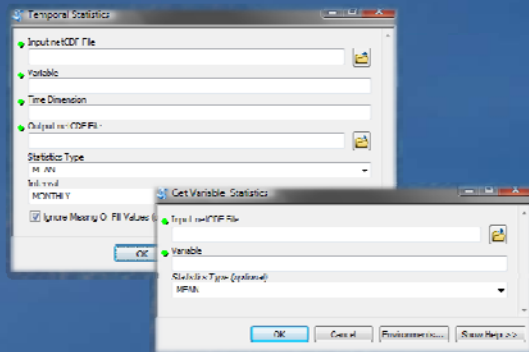


## Things to Consider...

- Embrace the Common Data Model (netCDF, HDF etc.)
- Use Data and metadata standards (OGC, CF etc)
- Make your data “spatial” (by specifying geographic or a projected coordinate system)
- Clearly define workflow and requirements
- Create sample tools where possible

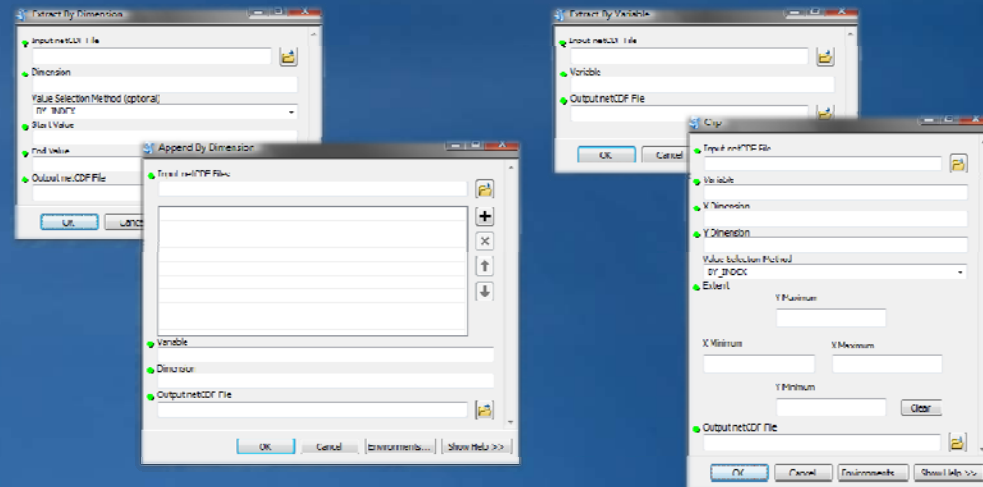
# Tools Under Consideration

- Temporal Statistics
- Get Variable Statistics



Analysis

- Clip
- Extract By Variable
- Extract By Dimension
- Append By Dimension



Data Management

## Future directions

- **Multidimension data management**
- **Temporal analysis tools**
- **Additional support for HDF5 using netCDF 4.x library**



- *What do you need?*

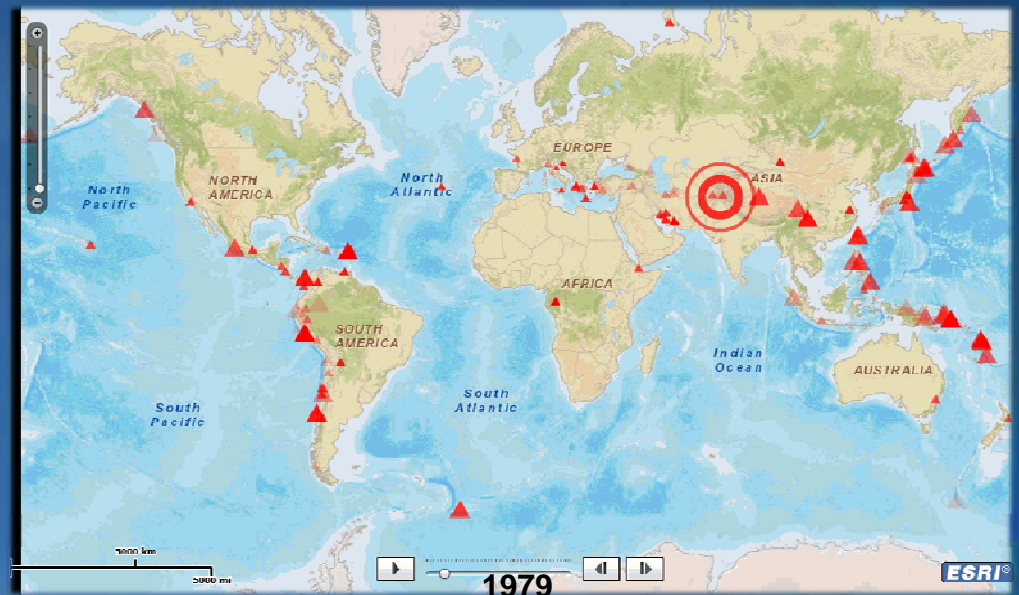
# Questions?

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Lead Product Engineer  
[nnoman@esri.com](mailto:nnoman@esri.com)

**Jeff Donze**  
ESRI Federal Business Development  
[jdonze@esri.com](mailto:jdonze@esri.com)

# Sharing Temporal Maps & Data with ArcGIS 10

- Publish time-aware maps
- Export videos or images, layer and map packages
- Visualize data
  - Access via REST API
  - Web API
    - FLEX
    - JavaScript
    - Silverlight
  - Time Slider web control

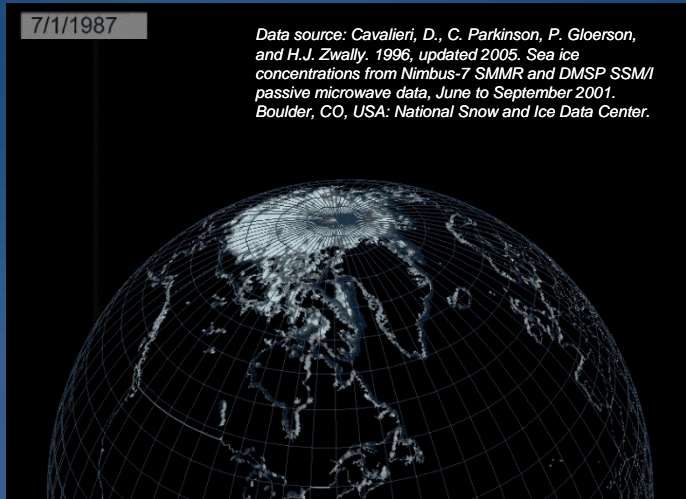


# How to store temporal data?

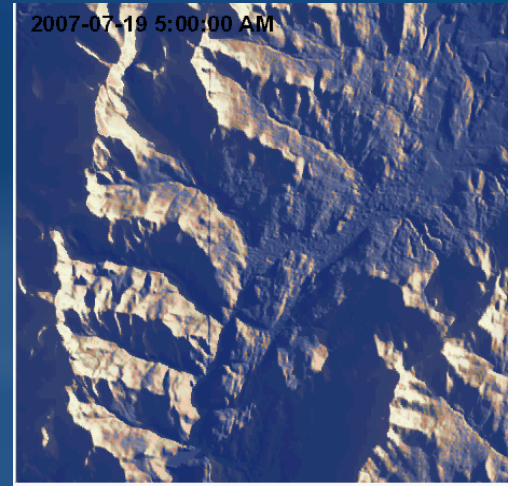
- **DATE is a special field type specific to time**
  - GeoDatabase provides DATE
  - If at all possible – use DATE type
  - DATE field should be indexed for faster query performance
- **Numeric and String fields**
  - YYYY
  - YYYYMM
  - YYYYMMDD                      YYYY/MM/DD                      YYYY-MM-DD
  - YYYYMMDDhhmmss              YYYY/MM/DD hh:mm:ss              YYYY-MM-DD hh:mm:ss
- **Time dimension in a netCDF variable**



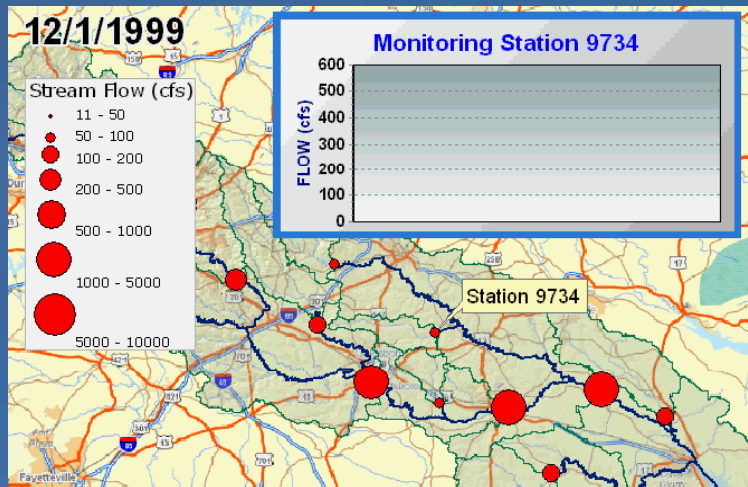
# Animation examples



**Sea ice concentration**

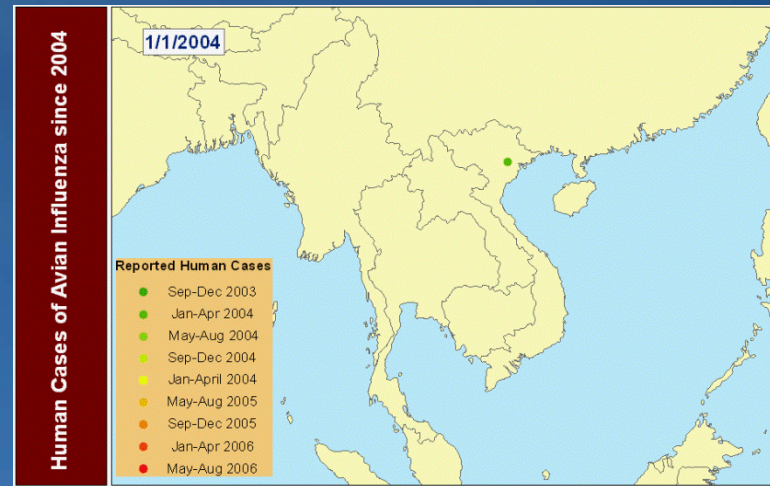


**Solar Insolation**



**Stream flow analysis**

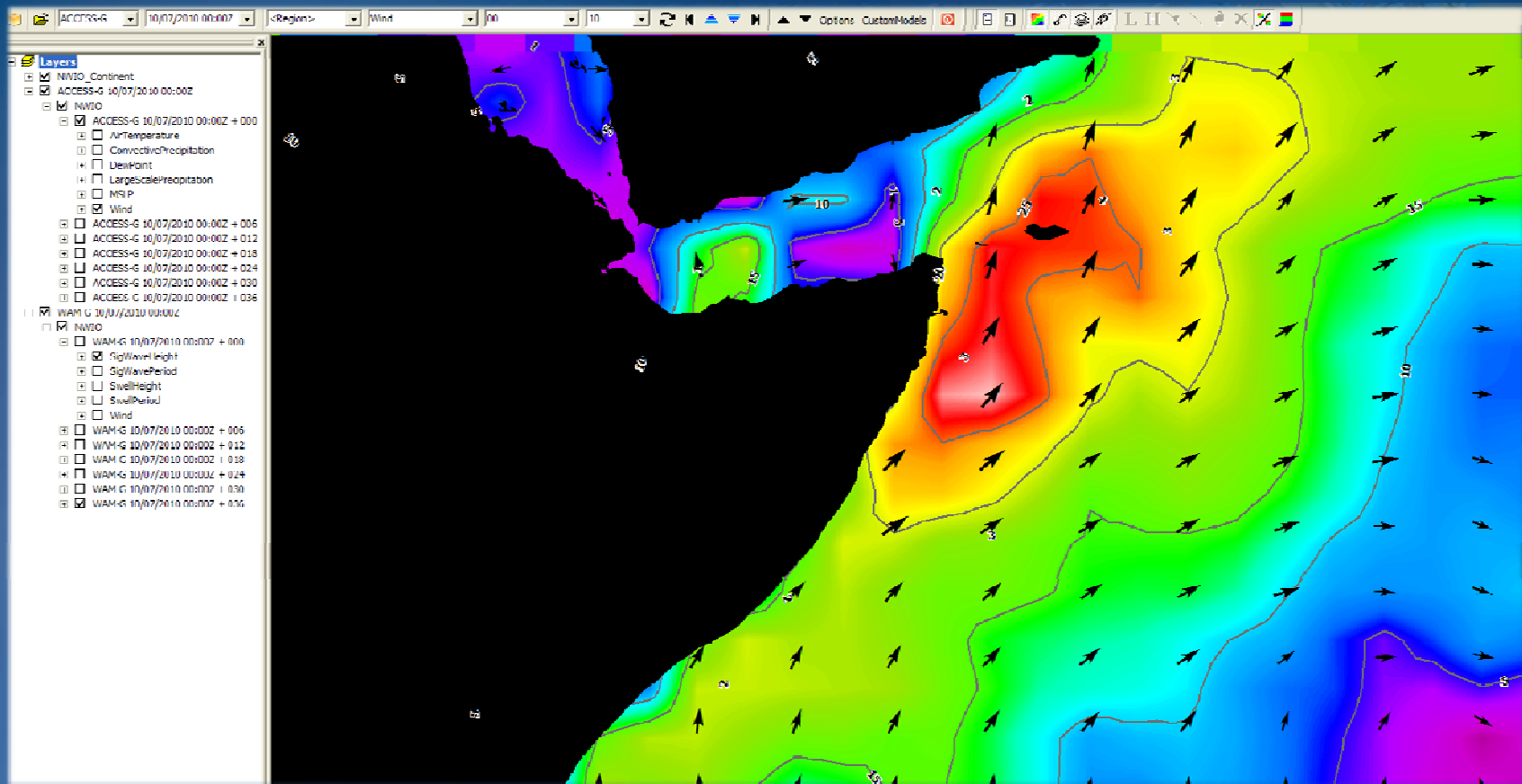
Data provided courtesy of Declan Butler - <http://declanbutler.info/blog/>



**Avian Influenza**



# Atmospheric Model Forecast – Surface Wind



Source: Hydrography and METOC Branch, Royal Australian Navy.