Analyzing Multidimensional Scientific Data in ArcGIS

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Outline

• **Part I**
  - ArcGIS Platform
  - Scientific Multidimensional Data
  - Ingest and Data Management
  - Data Exploration and Visualization

• **Part II**
  - Analysis
  - Extending Analytical Capabilities using Python
  - Publishing and Sharing Services
  - Consuming Services
ArcGIS - An Integrated Web GIS Platform

Web GIS

Providing Mapping, Analysis, Data Management, and Collaboration

Desktop  Web  Device

Portal

Geoinformation Model

Server  Online Content and Services

Apps  Identity

Access  Security

Services

Available on the Open Web . . . . . . and On-Premises
Scientific Multidimensional Data

- Stored in netCDF, GRIB, and HDF formats
- Multidimensional

- Ocean data
  - *Sea temperature, salinity, ocean current*

- Weather data
  - Temperature, humidity, wind

- Land
  - *Soil moisture, NDVI, land cover*
Scientific Data in ArcGIS - Vision

- Direct Ingest
- Data Management
- Analysis
- Visualization
- Share
Challenges

Manage
variety of formats
volume & velocity
redundancy

Analyze
portability
scalability
reproducibility

Share
integration
standards
accessibility
Representing Scientific Data in ArcGIS

- Data is represented as
  - Raster
  - Feature
  - Table

- Direct read
- Exports GIS data to netCDF
Ingesting Scientific data in ArcGIS

• Directly reads netCDF file using
  - Make NetCDF Raster Layer
  - Make NetCDF Feature Layer
  - Make NetCDF Table View

• Ingest OPeNDAP Service
  - Output dynamic multidimensional raster
  - Support Sub-setting

• Scientific data formats are supported in mosaic dataset
  - netCDF
  - HDF
  - GRIB
Ingesting Scientific data in ArcGIS Pro 2.1

- Directly reads netCDF, HDF, and GRIB file using Add Multidimensional Raster Layers dialog
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

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

• Current version 1.6

• You can use Compliance checker utility to check a netCDF file.
  http://cf-pcmdi.llnl.gov/conformance/compliance-checker/
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 1.6 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.
What about Aggregation?

- Create a seamless multi-dimensional cube from:
  - files representing different regions
  - files representing different time steps/slices

- **Mosaic dataset** supports multiple files and variables, normalize time and depth
Scientific data support in Mosaic Dataset

- Supports netCDF, HDF and GRIB
  - Spatial Aggregation
  - Temporal Aggregation
  - On-the-fly analysis

- Serve as Multidimensional
  - Image Service
  - Map Service
  - WMS

- Supports direct ingest
- Eliminates data conversion
- Eliminates data processing
- Improves workflow performance
- Integrates with service oriented architecture
ArcGIS Multidimensional Data Model

Multidimensional Mosaic Dataset in Geodatabase

- Ingest variables from netCDF, HDF & GRIB using raster types
  - Aggregate multiple variables, multiple files
- Support on-the-fly processing
Creating a Multidimensional Mosaic Dataset

*Using Geoprocessing Tools*

- Create a empty mosaic dataset
- Add select variables
MODIS: Land Surface Temperature
Behaves the same as any layer or table

• Display
  - Same display tools for raster and feature layers will work on multi-dimensional raster and feature layers.

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

• Animation
  - Multi-dimensional data can be animated through time dimension.

• Analysis Tools
  - Will work just like any other raster layer, feature layer, or table. (e.g. create buffers around points, reproject rasters, query tables, etc.)
Visualization of Scientific Data

• Slicing
• Temporal animation using Time Slider
• Dimensional animation using Range Slider
• Predefined renderer
• Temporal Profile
Changing Time Slice

Time = 1
Animating through Time using Time Slider
Animating through Depth using Range Slider
Visualization of Raster as Vectors

• New Vector Field renderer for raster
  - Supports U-V and Magnitude-direction
  - Dynamic thinning
  - On-the-fly vector calculation

• Eliminates raster to feature conversion
• Eliminates data processing
• Improves workflow performance
Temporal Profile

- Visualize the distribution of a variable over time
Spatial and Temporal Analysis

- Hundreds of analytical tools available for raster, features, and table
- Temporal Modeling
  - Looping and iteration in ModelBuilder and Python
On-the-Fly Processing using Raster Functions

- Several analytical functions are available out of the box
- Functions are chained together to create complex models
- Used to perform on-the-fly analysis
- Extend analytical capability using Python Raster Function
Choose from dozens of built-in functions or implement your own algorithm using Python.
WS16 = np.power(WS, 0.16)
Wind Chill = 35.74 + (0.6215 \times T) - (35.75 \times WS16) + (0.4275 \times T \times WS16)
T = Temperature
W = Wind Speed

... to compose a complex analytic model
Python Package: netCDF4-Python, SciPy

- netCDF4-python is included in 10.3/Pro
  - Read and write netCDF file
  - Conversion time values to date
  - Multi-file aggregation
  - Compression

- SciPy

- Python Raster Function
  [https://www.unidata.ucar.edu/software/netcdf/workshops/2012/netcdf_python/netcdf4python.pdf](https://www.unidata.ucar.edu/software/netcdf/workshops/2012/netcdf_python/netcdf4python.pdf)
Python – Extending Analytical Capabilities

**Supplemental tools**
- OPeNDAP to NetCDF
- Make NetCDF Regular Point Layer
- Make NetCDF Station Point Layer
- Make NetCDF Trajectory Point Layer
- Describe Multidimensional Dataset
- Get Variable Statistics
- Get Variable Statistics Over Dimension
- Multidimensional Zonal Statistics
- Multidimensional Zonal Statistics As Table

Community Developed Tools

- Marine Geospatial Ecology Tools (MGET)
  - Developed at Duke Univ.
  - Over 180 tools for import management, and analysis of marine data
    http://mgel.env.duke.edu/mget

- Australian Navy tools
  (not publicly available)
Disseminating

Professional geospatial analysts

Multivariate multidimensional mosaic dataset

Access / Identity

Apps

Desktop, Web, Device

Online Content and Services

Server
Sharing Scientific Data

- Mosaic Dataset > Share As Web Layer

Enable access to a dynamic representation of your information product as an image service
Sharing / WMS Support (for multi-dimensions)

- Map Service (supports WMS)
  - Makes maps available to the web.

- Image Service (supports WMS)
  - Provides access to raster data through a web service.

- Geoprocessing Service
  - Exposes the analytic capability of ArcGIS to the web.
HRRR Data Workflow

Model Generation

Time t

High Resolution Rapid Refresh Weather Model
3 km resolution
Hourly update

HRRR Dataset (GRIB)

Download

Server Accessible HRRR Dataset (GRIB)

Ingest:
Metadata
References to Source
Approx 30 records/Sec

Create Mosaic Dataset

Publish Mosaic Dataset

ArcGIS Image Server

Approx 30 records/Sec
Consuming your services

• In any ArcGIS application or any WMS client

• In a web map
  • Identify web services driven by maps or datasets
  • Bring service layers into a web map

• In a map-based application
  • Configurable apps
  • Story Maps
  • Web AppBuilder
  • Custom web apps using ArcGIS API for JavaScript
Presenting your Actionable Information | Customizing and Extending ArcGIS

Industry solutions

Workflow apps

App templates

App builders

Python API

Story Maps
Application(s): HRRR Explorer
The Living Atlas

- Imagery
- Basemaps
- Demographics & Lifestyle
- Boundaries & Places
- Landscape
- Community Maps
- Transportation
- Urban Systems
- Earth Observations
- Historic Maps
Services of Scientific Data

Online Imagery content that can be directly used:

- MODIS data
  - MODIS land cover 2000-2011
  - MODIS Vegetation Analysis
  - MODIS Greenland Sea Ice
- Live NOAA wind service
- NASA Global Land Data Assimilation (GLDS)
  - Soil moisture
  - Evapotranspiration
  - Snow pack
- More
Tell the story of your scientific data – Create Story Maps

Dead Zones in our Oceans

Dead zone or hypoxia, refers to a reduced level of oxygen in the water. Low oxygen dissolved in the water is referred to as a “dead zone” because most marine life either dies, or, if they are mobile such as fish, leave the area. Habitats that would normally be swarming with life become a biological desert. (NOAA)

1 Where are the Dead Zones?

Hypoxic zones can occur naturally, but hypoxic areas also can be created or enhanced by human activity. There are many physical, chemical, and biological factors that combine to create dead zones, but nutrient pollution is the primary cause of those zones created by humans. Hypoxia may also occur in the absence of pollutants. In estuaries, for example, because freshwater flowing from a river into the sea is less dense than salt water, stratification in the water column can result. Vertical mixing between the water bodies is therefore reduced, restricting the supply of oxygen from the surface waters to the more saline bottom waters. The oxygen concentration in the bottom layer may then become low enough for hypoxia to occur. Areas particularly prone to this include shallow waters of semi-enclosed water bodies such as the Wadden seas or the Gulf of Mexico, where land run-off is substantial. In these areas a so-called “dead zone” can be created.

http://dtc-sci01.esri.com/DeadZoneStoryMap/
Some Take Away

1. Mosaic Dataset is a robust data model that allows you to manage your large collections of scientific multidimensional data

2. Raster function(s) can help with your efficient on the fly computing that saves Time and Resources

3. Mosaic Dataset is a quick way to build the live web service

4. Make your scientific data and research output usable with repeatable workflow to your larger community
ArcGIS is a Scientific Collaboration Platform

- Discover
- Consume
- Contribute

ArcGIS Online or on-premise Portal
- Capability Choices
- Format Choices
- Services
- Files
- Dissemination with Choices
- Rich Information Products
- Analysis
- Remote Sensing & Scientific Data
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