Visualizing Hydrologic Data and Simulation Results with Python and ArcGIS

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Introduction

- Hydrologic flow models, produce large amounts of output, such as large cumbersome ASCII or binary files, which is often difficult to analyze and visualize.

- Python and ArcGIS can be used together to create custom tools to parse, extract, and visualize the relevant data from the model output files.
What we will talk about?

- Introduce ArcGIS, Python, and the NumPy module.
- Explain two tool packages: Animate Heads and C-Flow.
- Explain general methods for extracting data and visualizing.
- How the software, languages, and methods used to create these tools can be applied to other modeling package outputs.
Software and Languages

- Python
- NumPy
- ArcGIS
What is Python?

- High-level general-purpose programming language.
- Philosophy and design emphasizes code readability.
- Extensive standard library.
- Great for use as a scripting language or glue language to connect existing components together.
- Open source and freely distributed promoting 3rd party development.
The NumPy Module

- Numerical Python
- Extension to Python, adding support for large, multi-dimensional arrays and matrices.
- Contains a large library of high-level mathematical functions for use on arrays.
- Allows arrays to be saved to a binary .npy file for compressed storage and quick read access.
ArcGIS

- Geographical Information System developed by Environmental Systems Research Institute.
- ArcMap – Desktop application
- Contains extensions and tools for analyzing spatial data.
- ArcPy – Python site-package enabling integration of ArcGIS tools and functionality in Python.
Tool Packages

Animate Heads

C-Flow
Animate Heads

- Animate Heads extracts head values from a MODFLOW heads.out file and calculates the groundwater-level change or depth to water.

- Composed of three scripts:
  1. Extract Head Values
  2. Make Template
  3. Make Animation
**Extract Heads**

- **Extract Heads inputs:**
  - Folder of output head files
  - Number of rows
  - Number of columns
  - Layer
  - Time step
- **Outputs head values to binary NumPy arrays named by stress period.**
Make Template

- Make Template inputs:
  - Run type: DTW or GWL
  - Input arrays
  - Model grid shapefile
  - Start and stop stress period

- Make Template will process the requested calculation for each stress period.
- The script will get the min and max of all the calculation results and create a template shapefile.
Make Animation

- Make Animation inputs:
  - Template shapefile
  - Template mxd
  - Folder of calculated arrays
  - Frame rate
- Creates and combines images to make an animation based on the frame rate with the Arc Raster to Video tool.
- The output animation is .avi format.
Depth to Water
Groundwater Level Change
Groundwater Level Change Animation
C-Flow

- A post-processing toolbox developed to help analyze and visualize the flow terms in the MODFLOW output binary Cell-By-Cell file (CBCF).

- Composed of three scripts:
  1. CBCF Preprocessing
  2. Flow Terms to CSV
  3. Layer Maps
Layer Maps

- Layer Maps inputs:
  - Active cells shapefile
  - Layer number
  - Study Type
    - 1 for bottom flow
    - 2 for storage
    - 3 for pumpage
  - Displays seasonal view of flow terms for each model year.
Flow Terms To CSV

- Inputs:
  - User selected cells
  - Layer
  - Output type code
  - Numeric month if monthly output
- Output type codes:
  - 1 every stress period
  - 2 annual average
  - 3 one month a year
- Outputs are written to a CSV file.
Layer 2 Bottom Flow

Explanation

- Active Cell Boundary
- Lyr 2 Bottom Flow

-57325.109375 - 31017.345703
-31017.345702 - 14827.719727
-14827.719726 - 6687.908203
-6687.908202 - 2487.104004
-2487.104003 - 1007.782252
-1007.782251 - 0.000000
0.000001 - 0.000000
0.000001 - 856.351074
856.351075 - 3019.108887
3019.108888 - 6670.826660
6670.826661 - 14253.784180
14253.784181 - 34655.878906

0 15 30 60 90 120 Miles

Source: USGS EROS TANA AND
Layer 6 Pumping

Explanation
- Active Cell Boundary

Layer 6 Pumping
Jul 1989
-92108.289063 - -30816.853516
-30816.853515 - -6228.861816
-6228.861815 - -3141.009277
-3141.009276 - -1701.908203
-1701.908202 - -1030.075684
-1030.075683 - -309.056427
-309.056426 - 637.424988
637.424989 - 2273.765625
2273.765626 - 5129.361816
5129.361817 - 11171.548828

Active Cells

0 15 30 60 90 120
Miles
Conclusion

- If you know the pattern of the file and the key words you are looking for you can extract data from the file.

- If your data is based on a structured grid you can use the NumPy module to store and manipulate your data.

- Python can be used to import data to a structured grid in ArcMap to create images.

- Images can be created through time and combined to make animations with Python and ArcPy.