Spatial Analyst and Image Server Improvements for Water Resources

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Hydrology tool improvements in ArcGIS 10.6 / Pro 2.1

- Flow Direction and Accumulation tools
  - D-Infinity flow direction algorithm
  - Multiple Flow Direction flow direction algorithm
  - Flow Accumulation data type: DOUBLE
- Flow Distance tool (new)
- Improved performance and scalability
- *Now part of ArcGIS Enterprise Image Server*

platform big picture view

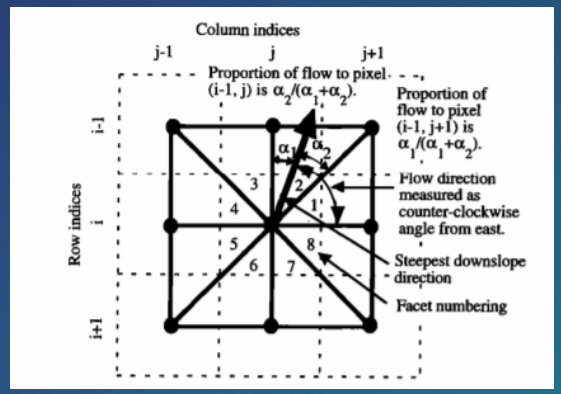
D-Infinity flow model

Steepest single direction

D8

46	37	82
62	77	83
82	79	80

D-Infinity best for modeling distributed hydrologic processes, such as runoff generation or erosion.



Steepest downslope direction

D∞

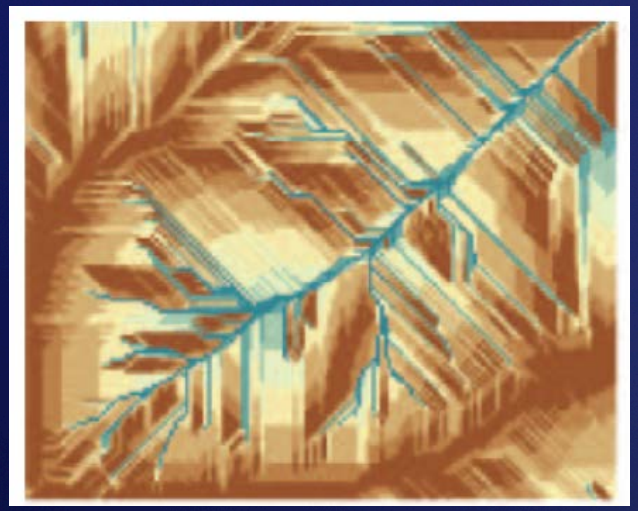
Convergent flow: flow to one downstream neighbor

Divergent flow: flow proportioned up to two downstream neighbors

Tarboton, D. G., (1997), "A New Method for the Determination of Flow Directions and Contributing Areas in Grid Digital Elevation Models," Water Resources Research, 33(2): 309-319.

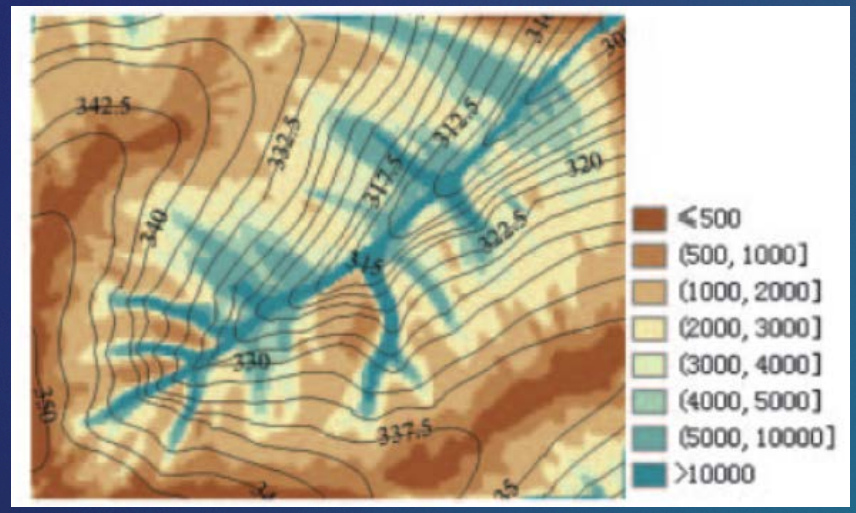
Multiple Flow Direction (MFD) flow model

- Better flow accumulation maps in low-relief areas
- Flow partitioning is adaptive to local terrain conditions.



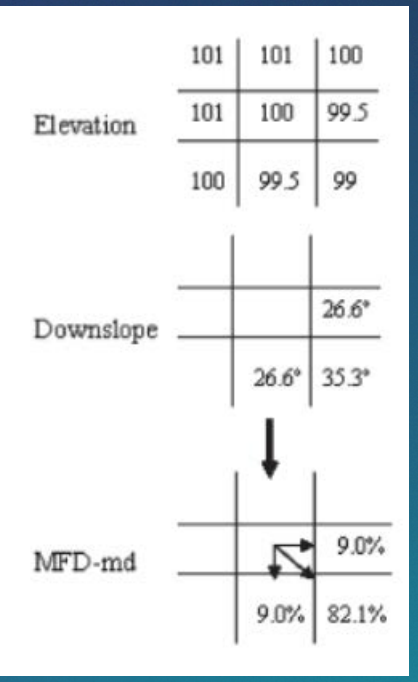
D8 Flow Accumulations

VS



MFD Flow Accumulations

MFD

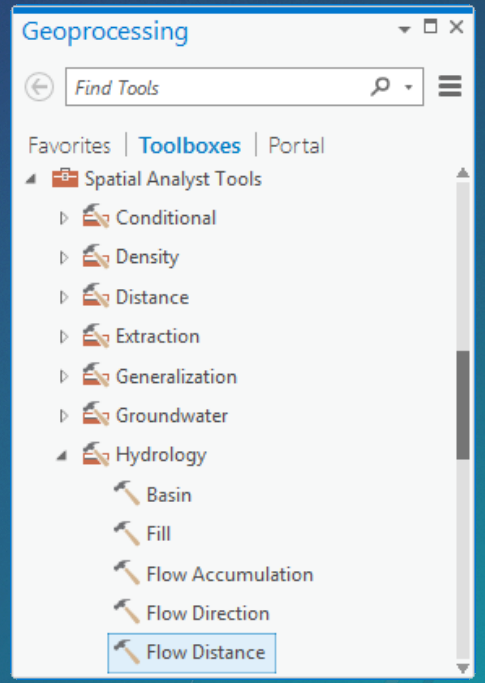


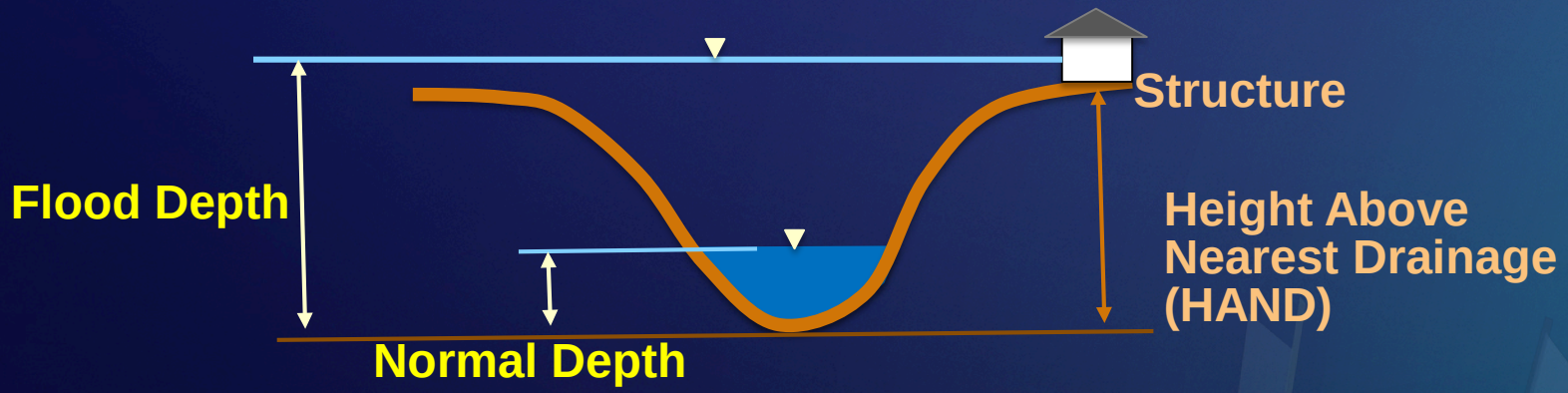
Flow proportioned to all downstream neighbor(s)

Qin, C., Zhu, A. X., Pei, T., Li, B., Zhou, C., & Yang, L. 2007. "An adaptive approach to selecting a flow partition exponent for a multiple flow direction algorithm." International Journal of Geographical Information Science 21(4): 443-458.

Flow Distance tool

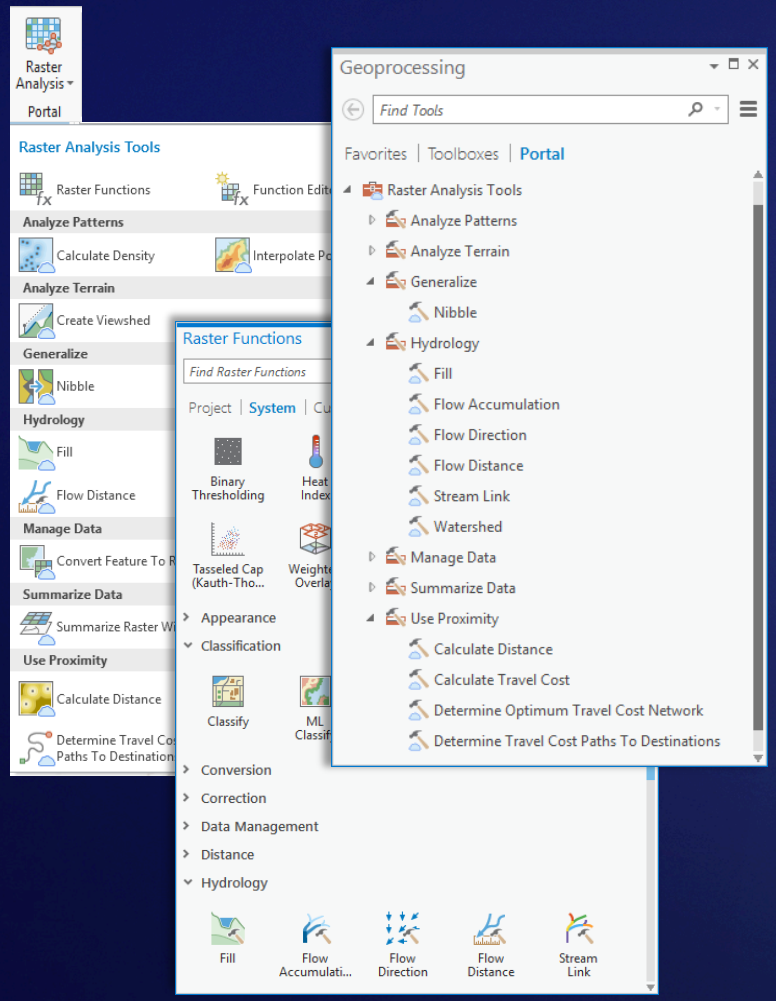
- Compute vertical/horizontal downslope distance to streams over single or multiple flow paths.
- Supports D8, D-Infinity and MFD algorithms for computing flow distance.
- Used in computation of Height Above Nearest Drainage (HAND). Flooding occurs when water depth is greater than HAND.



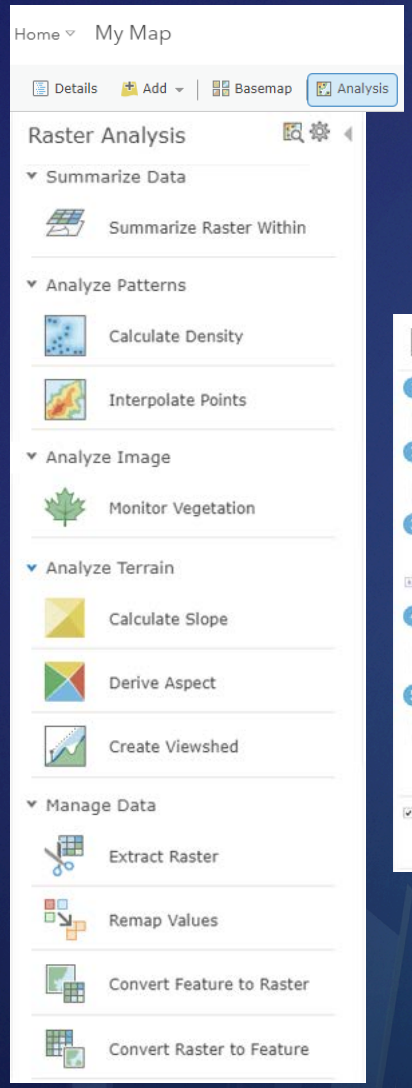


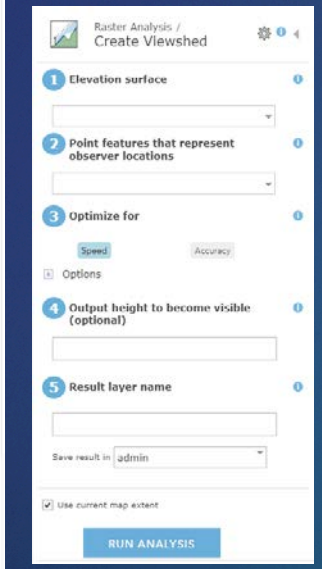
ArcGIS Enterprise Image Server (aka Raster Analytics)

Pro



Web





Python API

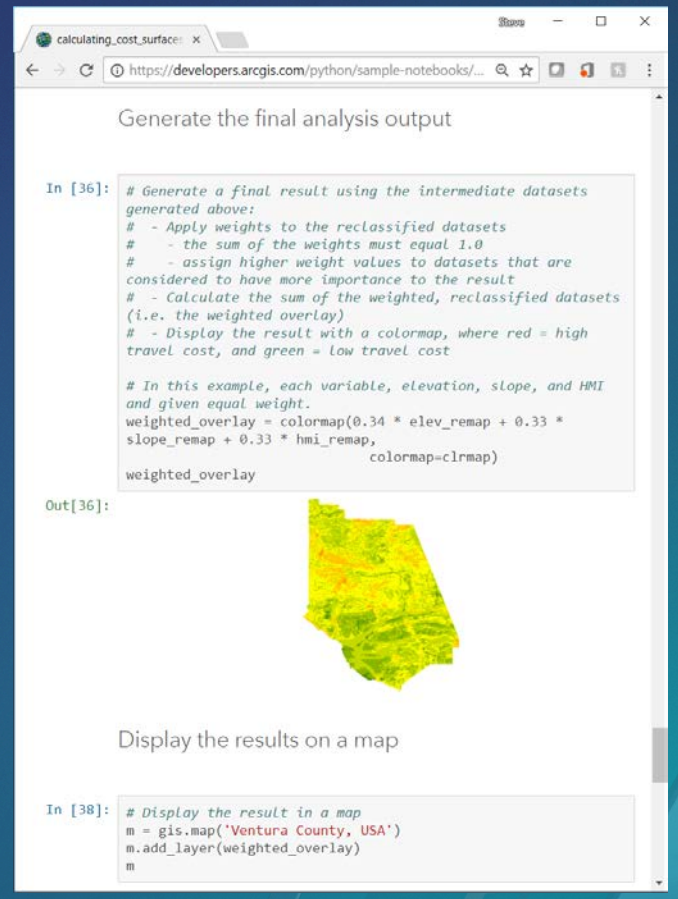
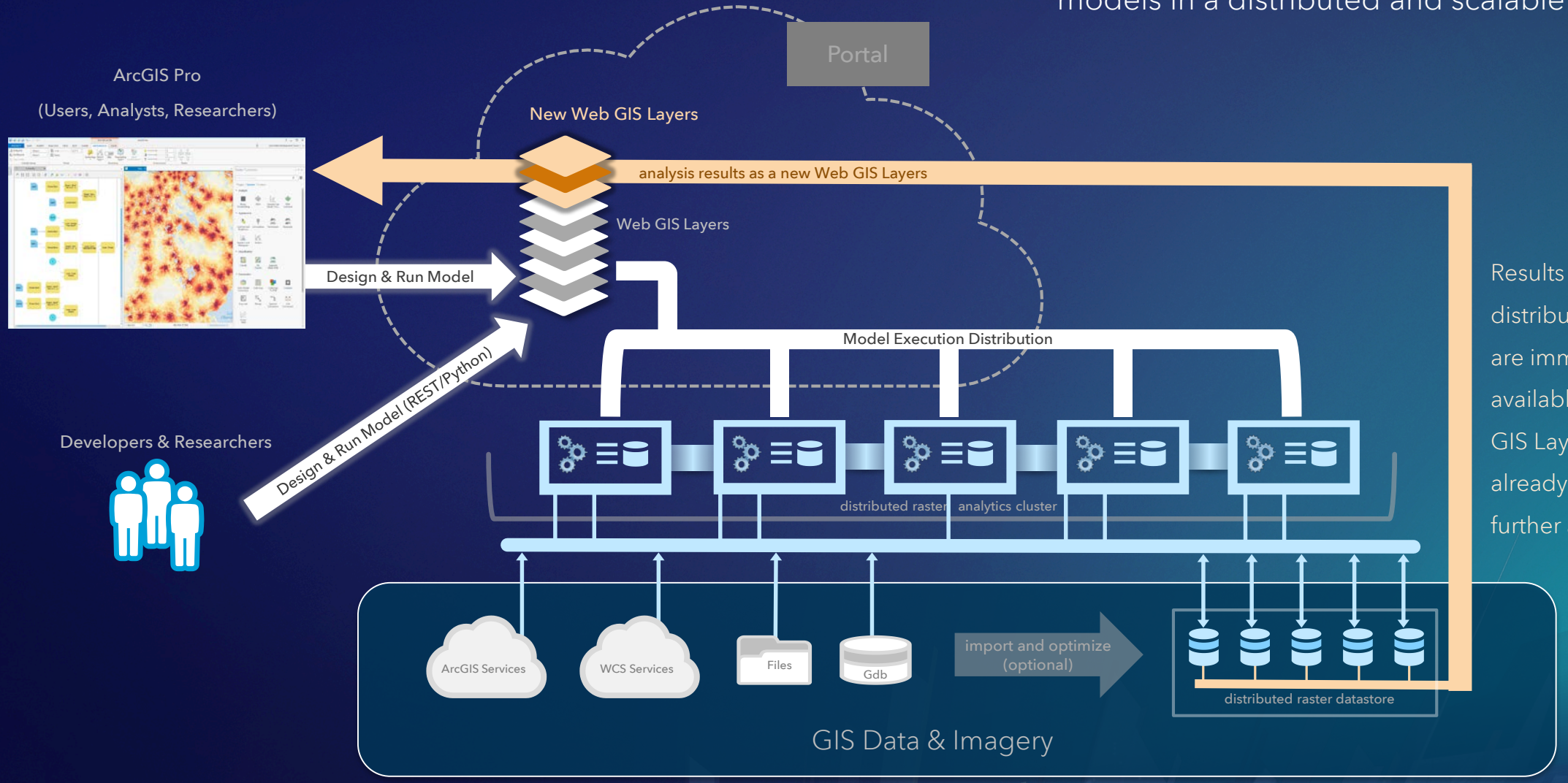


Image Server process flow

Raster Analytics can power systems that need to execute spatial analysis and image processing models in a distributed and scalable environment.



Results are stored in distributed storage and are immediately available as new Web GIS Layers which are already optimized for further analytics

Raster GIS and Image Analysis Tools

Math

Abs
Arithmetic
Band Arithmetic
Calculator
Divide
Exp
Exp10
Exp2
Float
Int
Ln
Log10
Log2
Minus
Mod
Negate
Plus
Power
Round Down
Round Up
Square
Square Root
Times
Bitwise And
Bitwise Left Shift
Bitwise Not
Bitwise Or
Bitwise Right Shift
Bitwise Xor
Boolean And
BooleanNot
Boolean Or
Boolean Xor
Equal To
Greater Than
Greater Than Equal
Is Null
Less Than
Less Than Equal
Not Equal
ArgStatistics
Cell Statistics
Statistics
ACos
ACosH
ASin
ASinH
ATan
ATan2
ATanH
Cos
CosH
Sin
SinH
Tan
TanH

Conditionals

Con
Set Null

Correction

Apparent Reflectance
Geometric Correction
Speckle Filtering (Lee,Frost,Kuan)
Thermal noise (Sentinel)
Radiometric Calibration (sentinel)

Data Management & Conversion

Raster to Vector
Vector to Raster
Colormap
Colormap To RGB
Complex
Grayscale
Remap / Reclass
Spectral Conversion
Unit Conversion
Vector Field
LAS to Raster
LAS Dataset to Raster
Clip
Composite
Extract Bands
Mask
Mosaic Rasters
Rasterize Features
Reproject
Nibble

Visualization & Appearance

Contrast and Brightness
Convolution
Pansharpening
Resample
Statistics and Histogram
Stretch

Interpolation

Empirical Bayesian Kriging
Interpolate Irregular Data
Nearest Neighbor
IDW
Swath

Surface Generation & Analysis

Aspect
Curvature
Elevation Void Fill
Hillshade
Shaded Relief
Slope
Viewshed

Analysis: Distance & Density

Euclidean Distance
Cost Distance
Least Cost Path
Kernel Density

Analysis: Band Math & Indices

NDVI / NDVI Colorized
SAVI / MSAVI / TSAVI
GEMI
GVI (Landsat TM)
PVI
Tasseled Cap (Kauth-Thomas)
Binary Thresholding

Analysis: Hydrology

Fill
Flow Accumulation
Flow Direction
Flow Distance
Stream Link
Watershed

Analysis: Image Segmentation & Classification

Segmentation (Mean Shift)
Training (ISO, SVM, ML)
Supervised Classification

Analysis: Overlay

Weighted Sum
Weighted Overlay

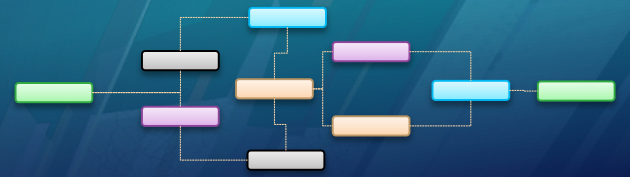
Analysis: Zonal

Zonal Statistics

Python

Custom Algorithms

Chain functions together into Raster Models and apply them to answer complex questions



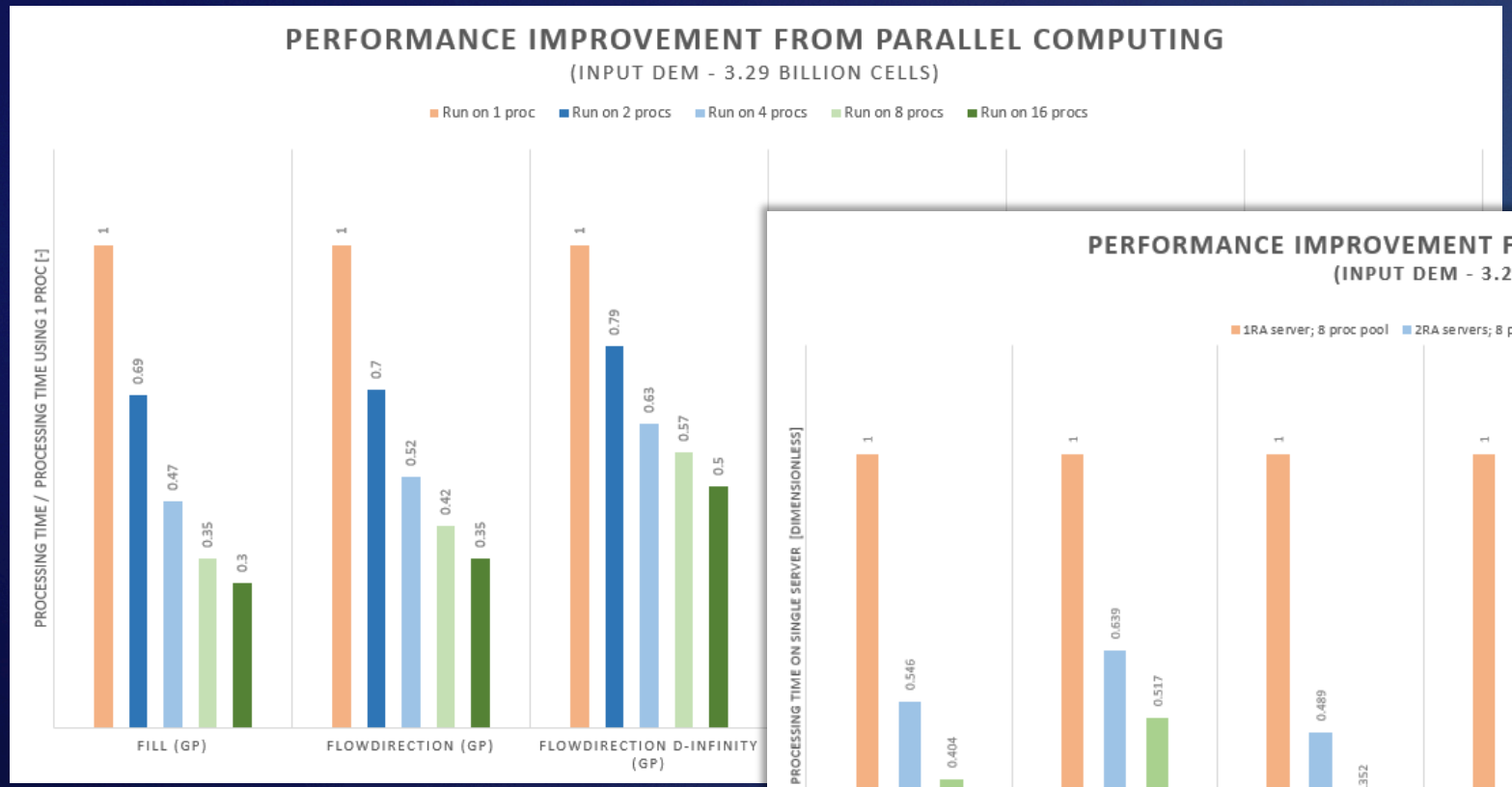
Hydrology tool performance and scalability

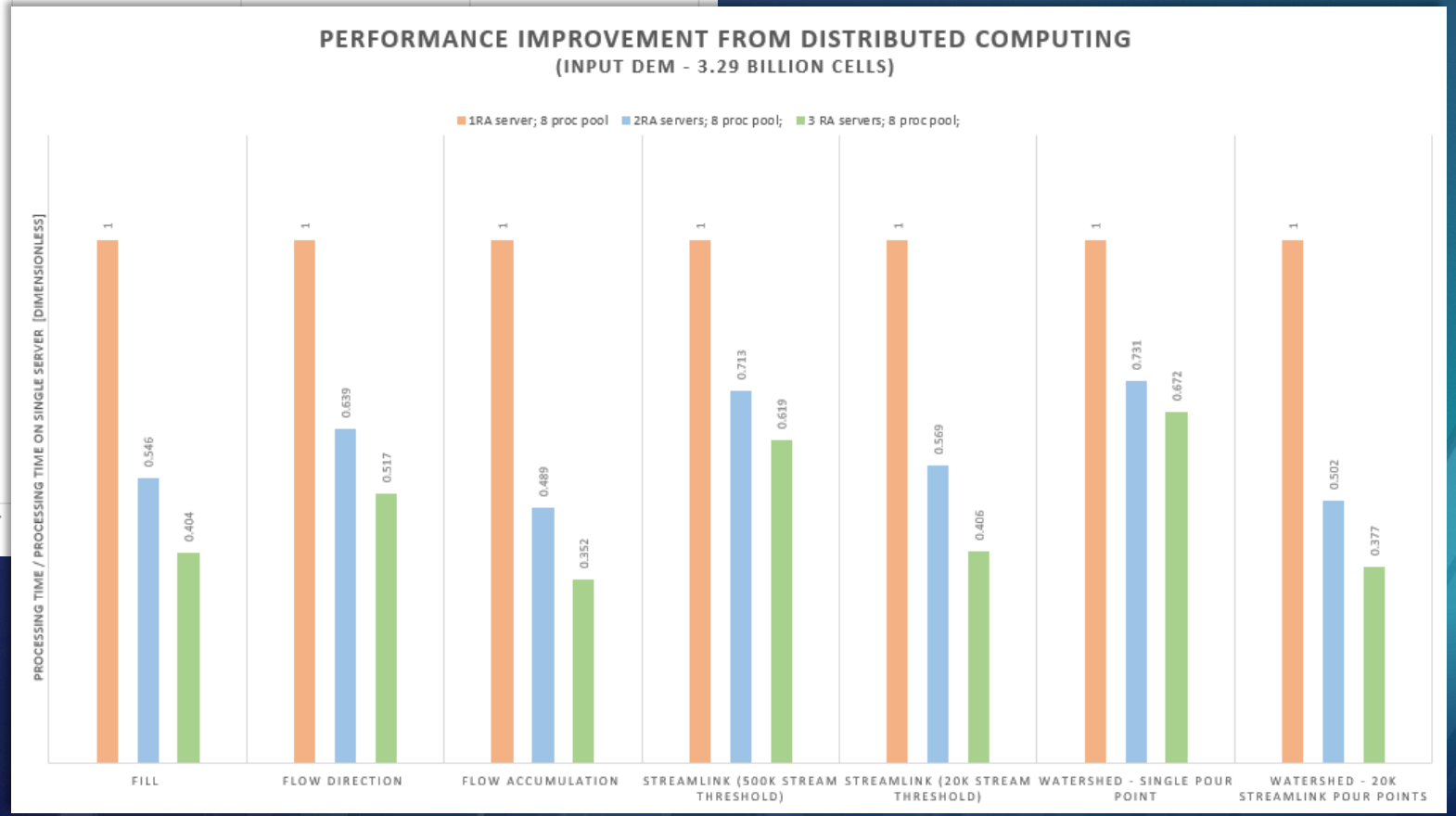
Distributed Computing on a Raster Analytics Cluster (4 nodes, 8 processors per node)
Local cluster with single file input and output data, no parallel I/O testing

- HUC2 Regions 7-12 | 10m | ~105 billion cells
  - Fill 18 hrs
  - Flow Direction D8 5 hrs
  - Flow Direction D∞ 13 hrs
  - Flow Accumulation 24 hrs

- The contiguous United States (CONUS) | 10m | ~228 billion cells
  - Fill 51 hours
  - Flow Direction D8 11 hrs
  - Flow Accumulation 75 hrs

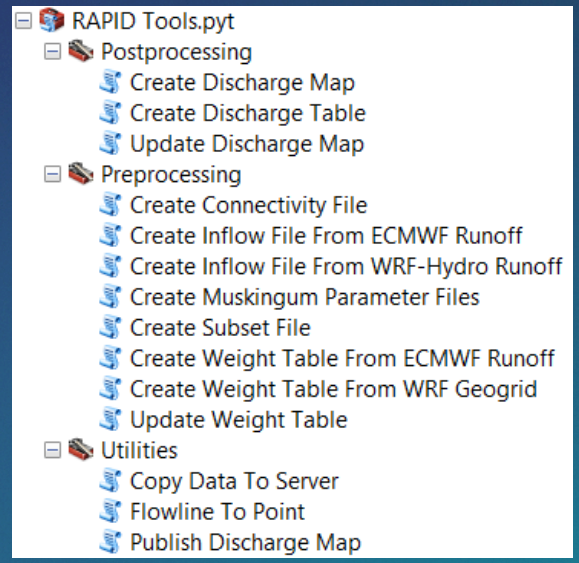
Scalability and Performance





Related open initiatives

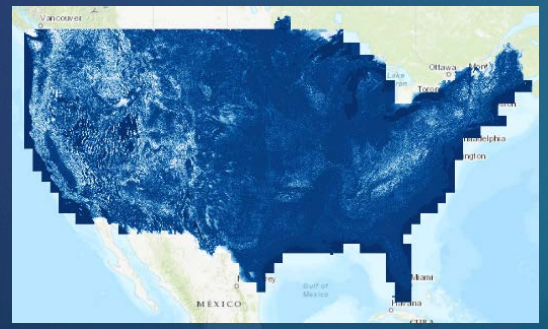
- Hydrologic downscaling and model preprocessing
  - https://github.com/Esri/python-toolbox-for-rapid
- Streamflow visualization
  - Python workflows and service scripts
  - shared with National Water Center and BYU, need documentation for public release to Github
- Flood inundation visualization
  - Python workflows and service scripts
  - shared with National Water Center, need additional work and documentation for public release to Github
- HAND computation
  - Will be added to Python API analysis example workbooks
  - New Spatial Analyst tool, with additional workflow tools added to Arc Hydro



Hydrology workflow scalability improvements

- Computing hydrologic characteristics and flow patterns for US
  - For predicting stream flow and forecasting floods
- Old single thread tools required manual chunking of input
  - Performance suffered over half billion cells
  - Manually chunked into 57 pieces for processing
  - Several CPU months of compute plus human time reassembling
- Now running 500x larger data on a distributed cluster
  - Processing changed from several months to 2 days

30m US – 25 Billion cells
57 separate processing units



10m US – 230 Billion cells

A new paradigm in water understanding

- Hourly stream flow on 2.7 million stream reaches
- Working toward hourly national flood inundation forecasts
  - Much finer spatial and temporal scale than currently available


esri
THE
SCIENCE
OF
WHERE