ArcGIS API for Python: Imagery and Raster Analysis on your Web GIS

Atma Mani, Chunming Peng, Nawajish Noman

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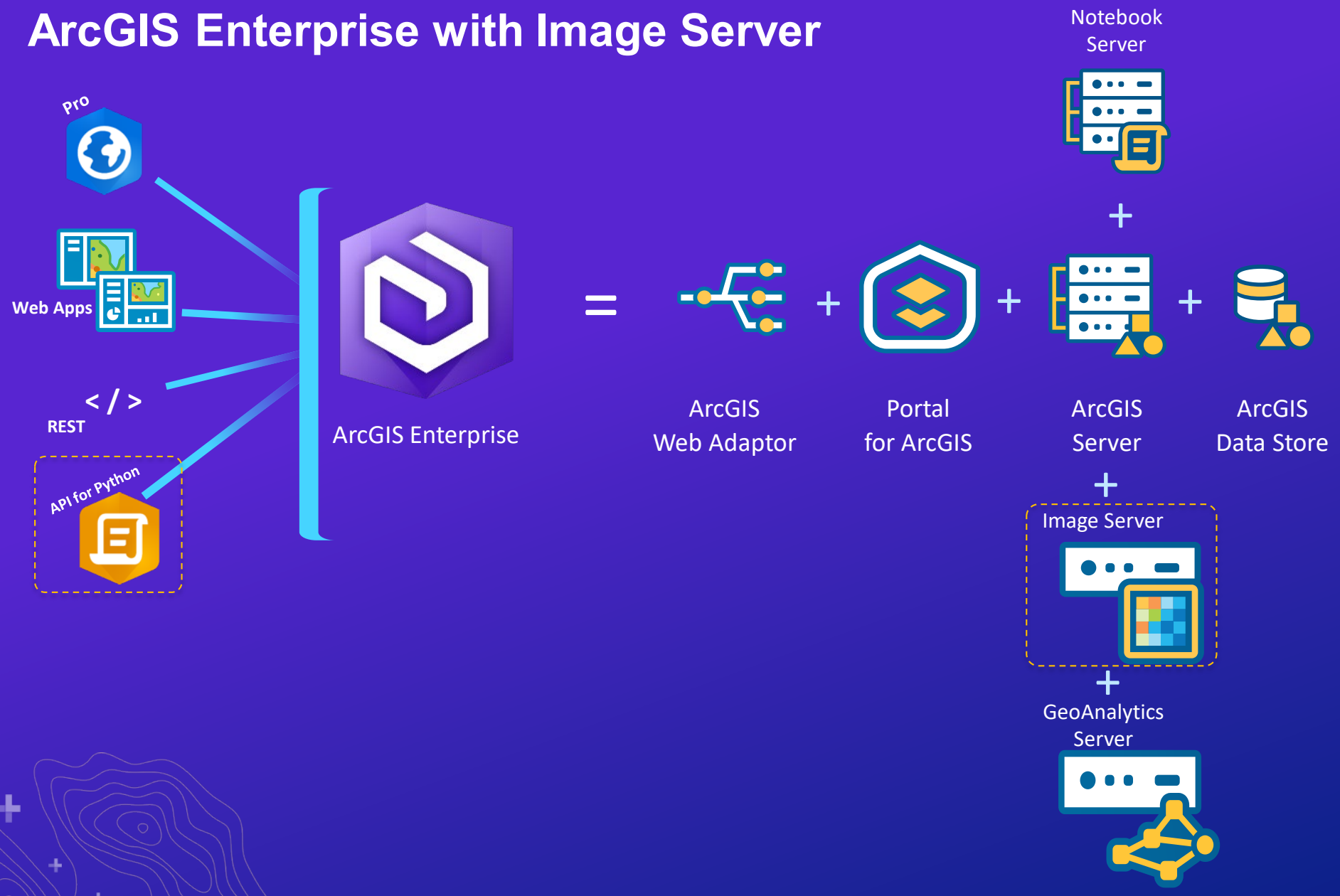
Talk outline

- Introduction to imagery and raster analysis on Web GIS
- Getting to know the ArcGIS API for Python's `raster` module
- Raster analysis concepts – a crash course
- Demos
  - Imagery analysis
  - Raster analysis
- Conclusion

Imagery and Raster analysis on the Web GIS

An introduction

ArcGIS Enterprise with Image Server



ArcGIS API for Python – over 2300 methods & functions

Web GIS Administration

Users - create, delete, update, credit budgeting, privileges, licenses, user groups, transfer ownership

Security – auth models, user roles, portal & server licenses, certificates, theming, collaboration, password policies, OAuth, Web Adaptor, Webhooks

Servers – datastores, federation, logs, machines, services, reports, sites, config store, jobs

Web GIS Content Management

Items - Publishing, cloning, updating items, editing features

Distributed editing – versions, replicas, syncs, attachments, parcel fabrics, utility networks, validations

ArcGIS Apps – manage content for hub, workforce, storymaps, survey123, tracker

Spatial Modeling

Spatially Enabled DataFrames, spatial overlays, joins, tessellations, merging layers, data extractions

Analyzing patterns – density, hot spots, outliers, interpolation, clusters

Prediction – regression, random forests

Topographic – elevation profiles, viewsheds, watersheds, trace downstream

GeoEnrichment

Summarization – describe data, aggregations, summarize nearby & within, summarize center & dispersion
GeoAnalytics – big data analysis

Imagery analysis

Data management – add, edit, delete raster, raster collections, raster stats,

Information extraction – over **170** raster functions, raster algebra

Ortho mapping – compute sensor model, corrections, generate ortho mosaic, DEM, surfaces

Location Analytics

Suitability - similarity search, dwell locations, detect incidents, geocoding

Network analysis – OD cost matrix, service areas, location allocation, plan routes, closest facilities

Geocoding

Spatial Machine Learning

SeDF – integration with Scikit-Learn, other ML libs

Imagery – classification, segmentation, trend raster, spectral unmixing

Deep learning – detecting objects, classifying pixels, classifying objects, instance segmentation, NLP, managing models, fine tuning.

Visualization

Smart mapping, 2D <-> 3D map widget, author web maps, scenes,

Renderers - matplotlib style renderers for map symbols, chart using Python charting libraries, represent raster functions as task graphs

Getting to know the ArcGIS API for Python's `raster` module

ArcGIS API for Python – `arcgis.raster` module

ImageryLayer

Properties:
- band_count
- properties
- cache_manager
- mosaic_rule
- multidimensional_info
- pixel_type
- raster_info
- rasters
- tiles
- ....

Methods:
- save()
- export_image()
- filter_by()
- get_samples()
- identify()
- key_properties()
- compute_histograms()
- project()
- query()
- draw_graph()
- set_filter()
- temporal_profile()
- to_features()
- .....

ImageryLayerCacheManager

Properties:
- jobs
- ....

Methods:
- edit_tile_service()
- cancel_job()
- import_tiles()
- update_tiles()
- job_status()
- ....

RasterManager

Methods:
- add()
- delete()
- update()

ImageryTileManager

Methods:
- export()
- estimate_size()
- image_tile()

Raster

Properties:
- band_count
- is_multidimensional
- properties
- spatial_reference
- pixel_type
- multidimensional_info
- ....

Methods:
- read()
- export_image()
- save()
- write()
- set_engine()
- get_raster_bands()
- .....

RasterCatalogItem

Properties:
- properties
- ics_to_pixel
- ....

Methods:
- image()

arcgis.raster.analytics

- classify()
- calculate_density()
- convert_raster_to_feature()
- generate_raster()
- segment()
- .....

arcgis.raster.functions

- apply()
- band_arithmetic()
- colormap()
- focal_statistics()
- ml_classify()
- ... over 140 functions

arcgis.raster.gbl

- calculate_distance()
- cost_allocation()
- distance.....()
- flow_accumulation()
- .....

arcgis.raster.orthomapping

- generate_dem()
- generate_orthomosaic()
- compute_seamlines()
- compute_sensor_model()
- ...

Raster analysis – essential concepts

Nawajish Noman

ArcGIS Has Five Core Capabilities for Imagery

Content

Landsat
Weather
Small Sats
High-Resolution Satellites
Community Imagery
Radar
Video
Aerial Photos
All Major Sensors
Sentinel
Drones

Analysis

Indexes
Change Analysis
Classification
AI / Deep Learning
Raster Processing Functions

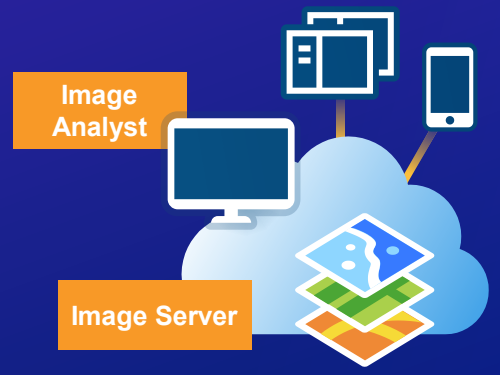
Map Production

Drone Mapping
Ortho Mapping
Stereo
Drone2Map
Seamless Orthophotos
DTM Generation
Ortho Maker

Visualization & Exploration

Image Space and Mensuration
Full-Motion Video
Oriented Imagery
Street Views
Charting
Spectral Profile
Temporal Profile

Management & Dissemination



Integrated and Massively Scalable

Image Processing

- Correction
  - Perform geometric and radiometric corrections to get rid of flaws caused by
    - the curved shape of the Earth,
    - the imperfectly transparent atmosphere,
    - daily and seasonal variations in the amount of solar radiation
    - imperfections in scanning instruments, among other things.
- Visualization and Appearance
  - Enhances the appearance by modifying the brightness and contrast
  - The Convolution functions sharpens an image, blurs an image, detects edges
  - The Pansharpening function fuses a higher-resolution panchromatic image with a lower-resolution, multiband raster dataset to increase the spatial resolution of the multiband image.

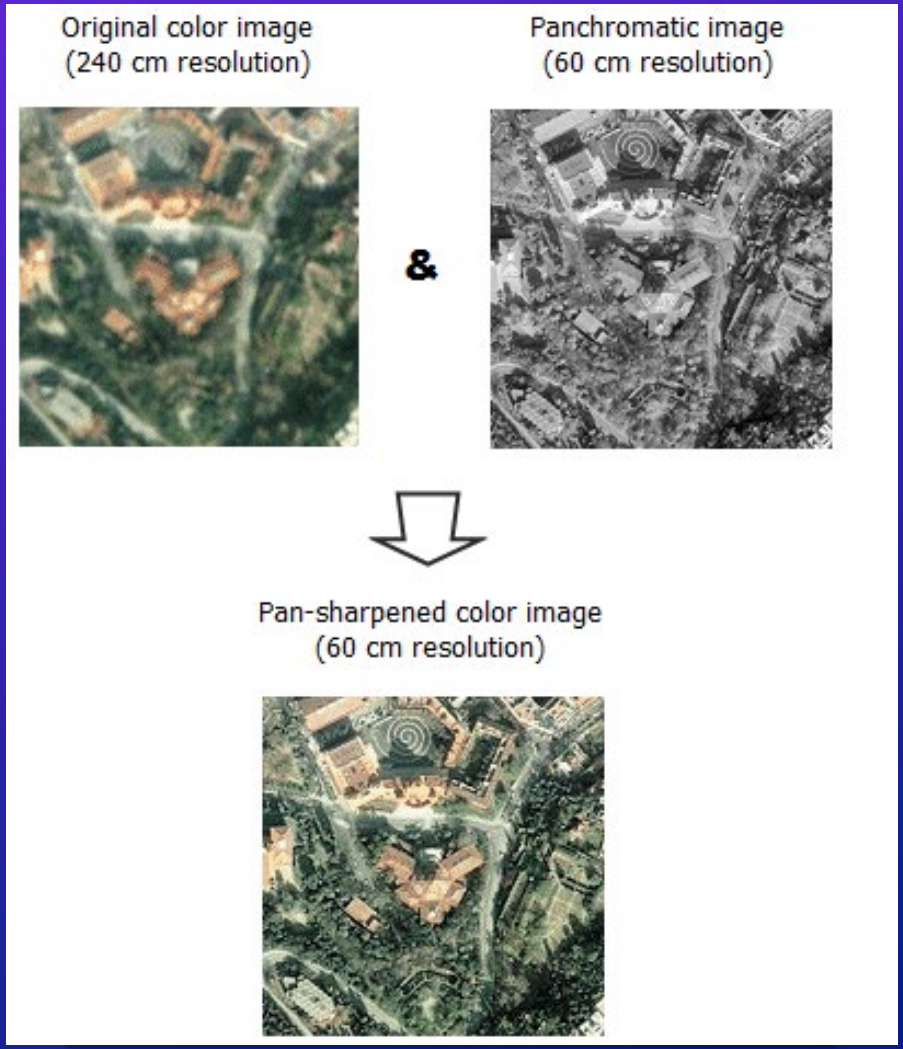


Image Processing (cont.)

- Band Math and Indices
  - Image indices are computed from multiband images to emphasize a specific phenomenon.
  - The normalized difference vegetation index (NDVI) is a standardized index allowing you to display greenness, also known as relative biomass.
    - High values represent forest areas and lush vegetation.
    - Moderate values represent areas of shrubs and grassland
    - Very low values represent areas of little to no vegetation, such as concrete, rock, or bare soil.
    - Extremely low or negative values represent areas with no vegetation at all, such as cloud, water, snow.
  - The NDVI Colorized function applies the NDVI function on the input image, and then uses a color map or color ramp to display the result.

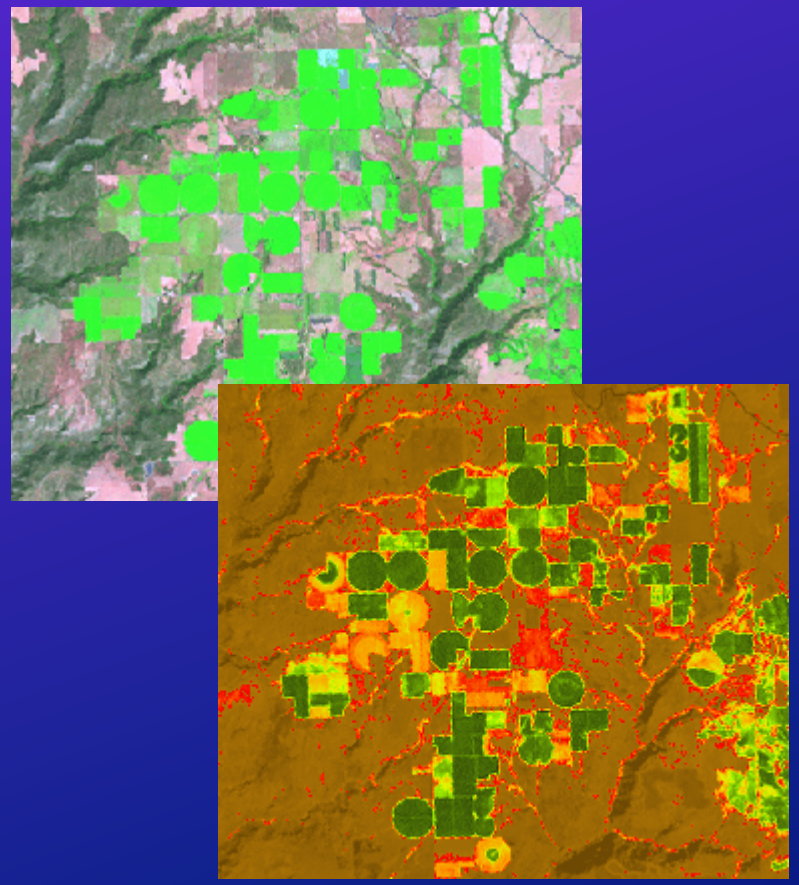


Image Processing (cont.)

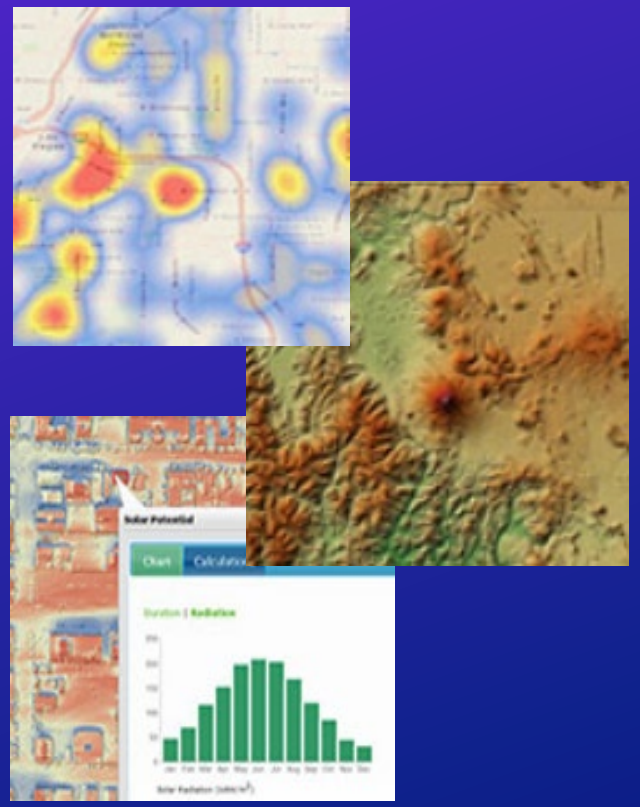
- Image Segmentation and Classification
  - Perform object based image classification on image segments or pixels based classification using a variety of supervised and unsupervised techniques.
    - Supervised/unsupervised classification
    - Object based and pixel based segmentation
    - Accuracy assessment
    - SVM, random trees, ISO clustering, MLC

Raster Analysis

- Distance Analysis
  - Apply distance functions to create maps of distance, and cost distance from locations, the shortest path two locations, or the optimal travel path between multiple locations.
- Suitability Modeling
  - Determine an ideal location for operations, considering multiple factors that affect suitability. Combine categorial (land use, soil type) and continuous (slope, property value) variables to create a suitability map. Then use Locate Regions to find the best locations.
- Hydrological Analysis
  - Derive surface flow patterns from a DEM. Create watersheds, stream networks, flow distance, and other hydrological characteristics. Summarize landscape data as input to hydrologic and hydraulic models, as well as flood inundation and erosion models.

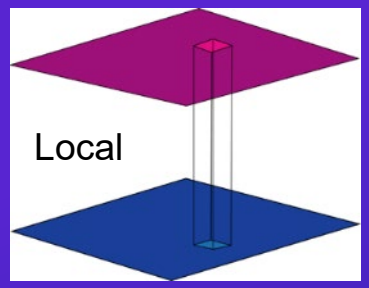
Raster Analysis (contd.)

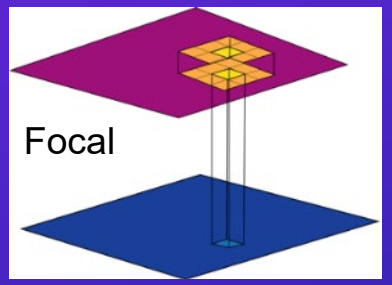
- Interpolation and Density
  - Predicts values and creates a continuous surface from sample data points, such as elevation, rainfall, chemical concentrations, and noise levels.
- Derivation of land surface characteristics
  - Create hillshade, slope, aspect, curvature, solar insolation, and visibility to help solve spatial problems
- Statistical Analysis
  - Perform calculations on a per-cell basis between multiple datasets, based on local, neighborhood, or zonal functions.
- Generalization
  - Either clean up small erroneous data in the raster or generalize the data to get rid of unnecessary detail for a more general analysis.
- Map Algebra
  - An easy-to-use and powerful way to perform raster analysis as algebraic expressions.

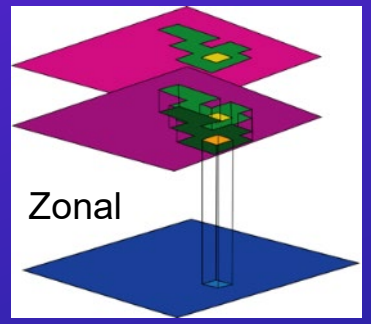


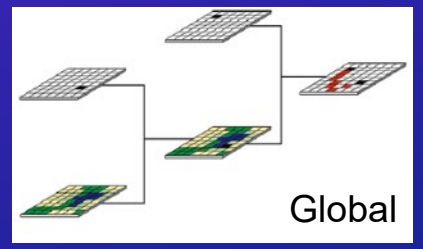
Types of Raster Analysis Operations

- Distributed Raster Analysis supports
  - Local/Focal analysis
    - Most raster functions
    - Custom python raster functions
  - Zonal analysis
    - Zonal statistics
  - Global analysis
    - Hydrology Analysis
    - Cost Distance







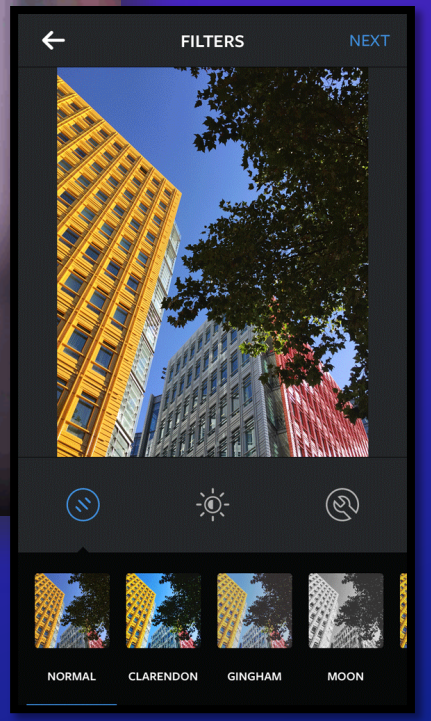


Distributed computation - Level of difficulty

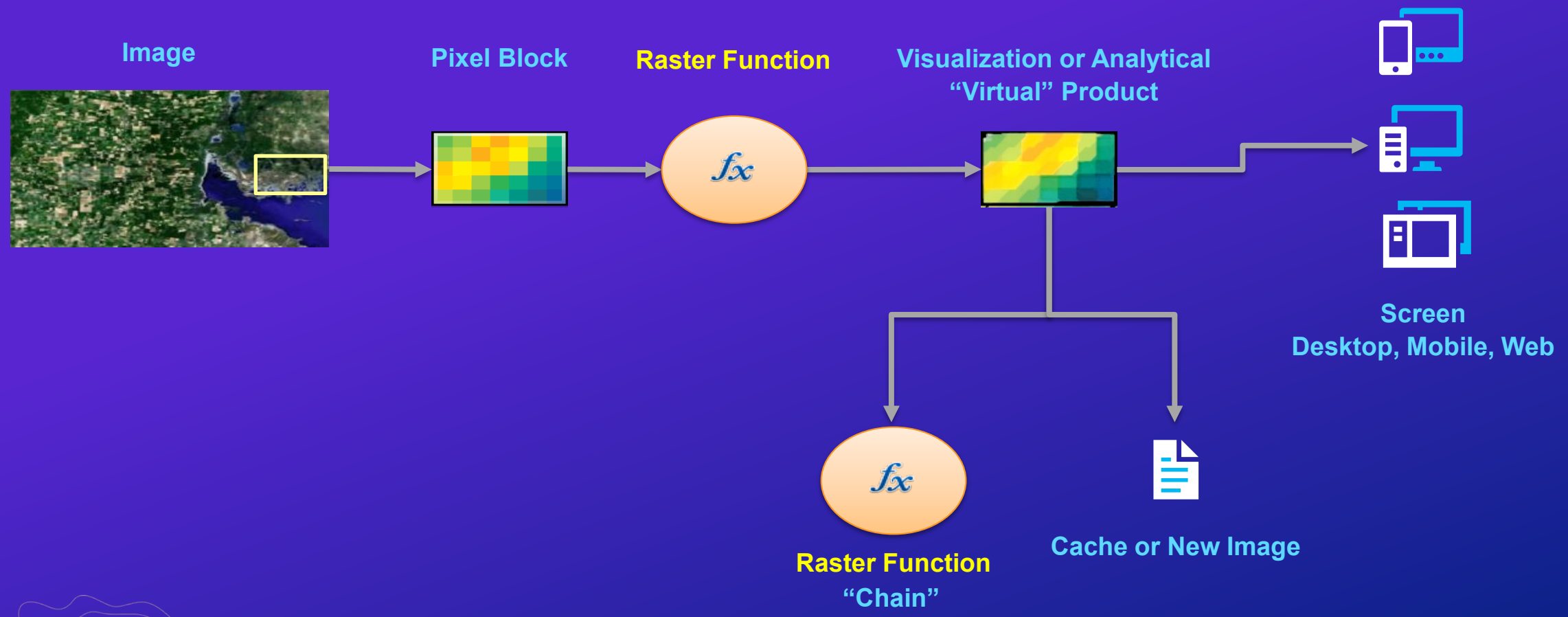
Different type of operation poses different challenge to distributed computation

Raster function

- Process on-demand – at display scale resolution

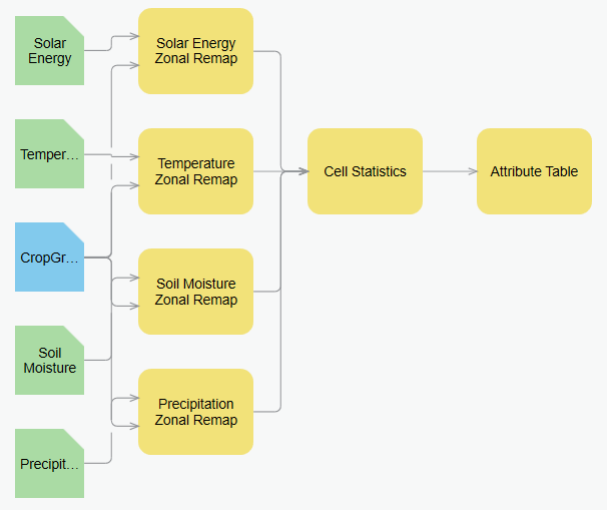


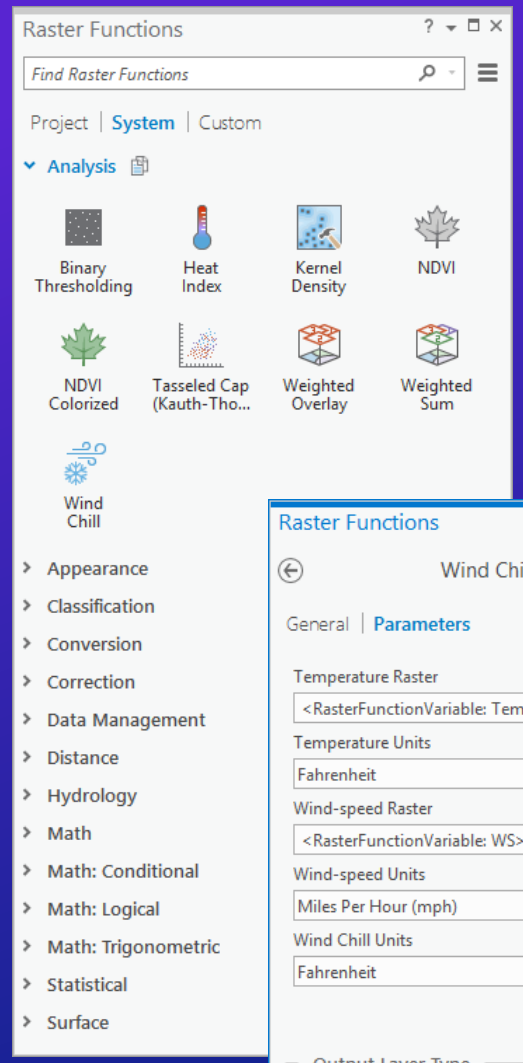
Raster Function & Raster Function Chains



On-the-Fly Processing using Raster Functions

- Processing is not permanently applied to the data; instead, it is applied on the fly as the imagery and rasters are accessed.
- Several analytical functions are available out of the box
- Functions are chained together to create complex model
- Can be saved as a Raster Function Template (RFT)
- They can be applied to the imagery layer or embed into a mosaic dataset
- Extend analytical capability using Python Raster Function





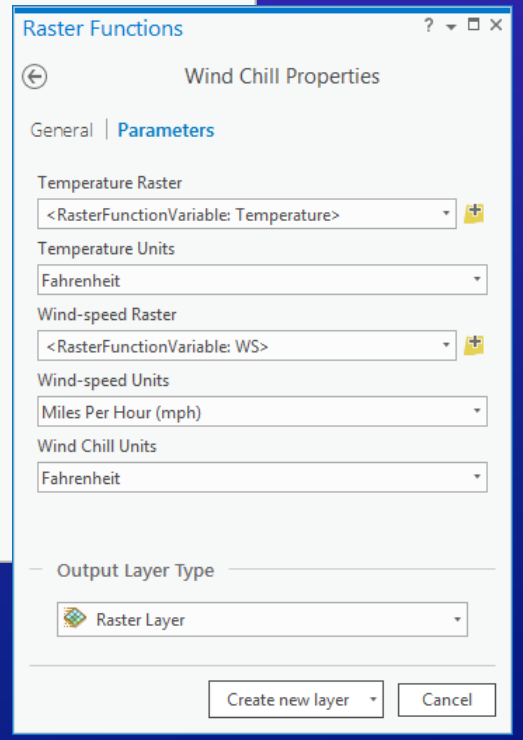
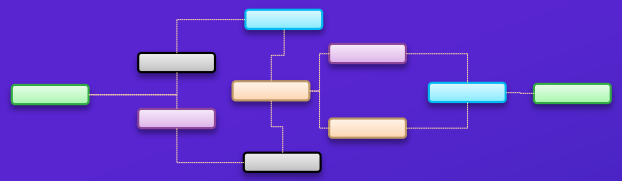


Image Processing & Raster Analysis Functions



Multiband Math

Arithmetic
Band Arithmetic

Analysis: Band Math & Indices

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

Statistics

ArgStatistics

Visualization & Appearance

Contrast and Brightness
Convolution
Pansharpening
Resample
Statistics and Histogram
Stretch

Correction

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

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
Region Group
Lookup

Interpolation

Interpolate Irregular Data
- Nearest Neighbor
- IDW
- EBK
Swath

Surface Generation & Analysis

Aspect
Curvature
Elevation Void Fill
Hillshade
Shaded Relief
Slope
Contour

Python

Custom Algorithms

Analysis: Image Segmentation & Classification

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

Analysis: Overlay

Weighted Sum

Statistics:

Zonal Statistics
Cell Statistics
Focal Statistics *

Math

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

Analysis: Distance & Density

Euclidean Distance
Cost Distance
Least Cost Path
Kernel Density
Path Allocation
Path Distance
Corridor
Path Distance backlink

Analysis: Hydrology

Fill
Flow Accumulation
Flow Direction
Flow Distance
Stream Link
Watershed

Analysis: Overlay

Weighted Overlay

Surface Generation & Analysis

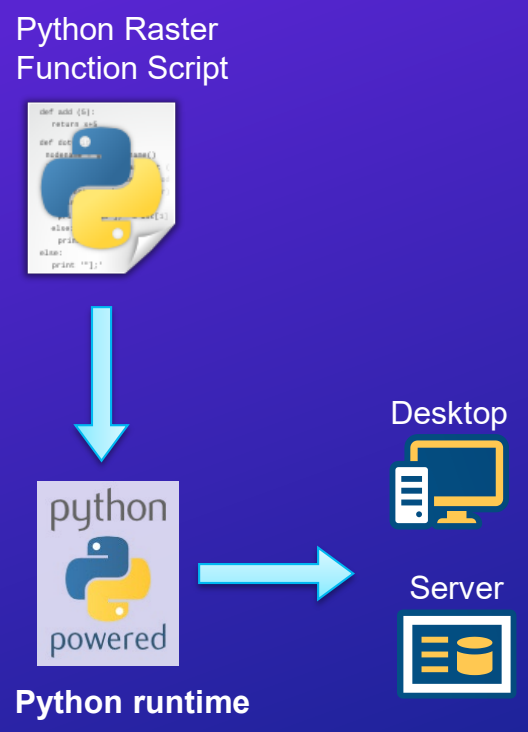
Viewshed

Data Management

Nibble

Python Raster Function – Extending Analytical Capability

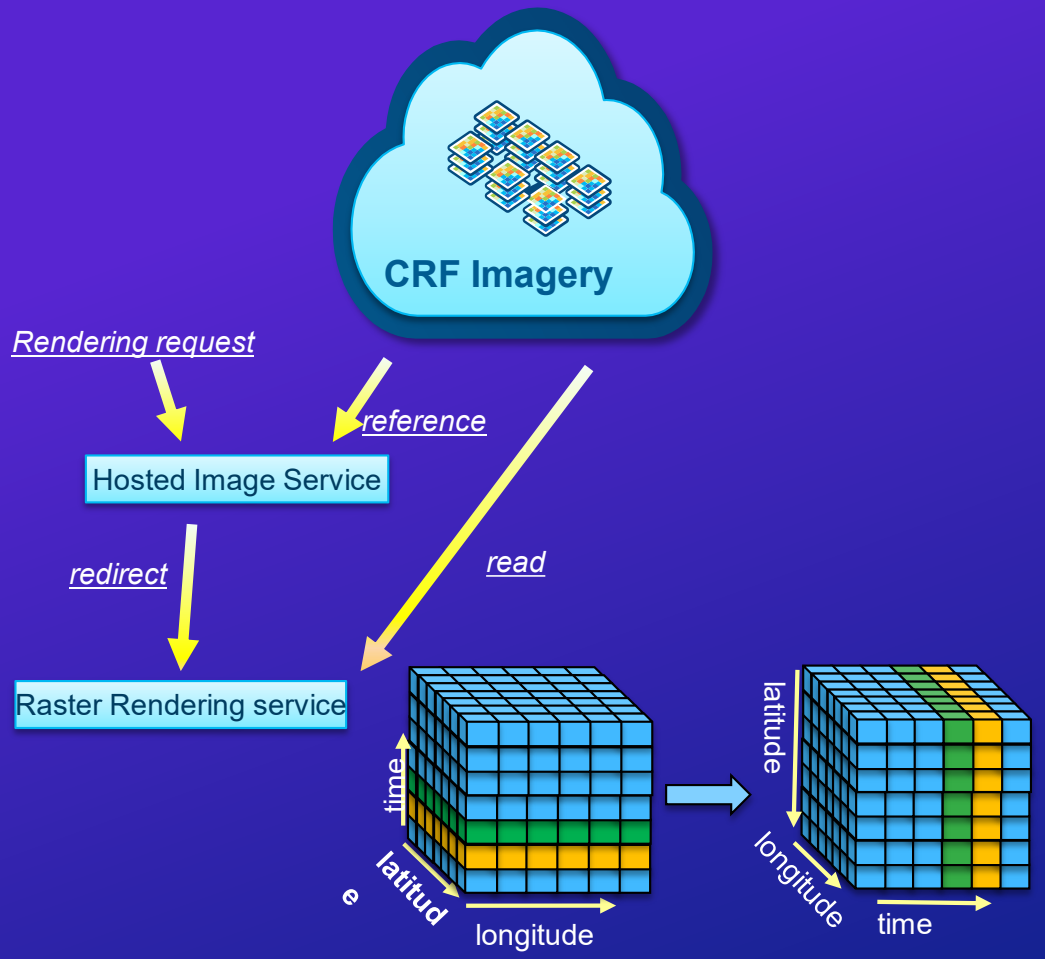
- Transforms Rasters - Image processing and analytic algorithms in Python.
- A Python Script that defines a Custom Raster Function Class
- Not part of ArcPy or ArcGIS API for Python
- Allows ArcGIS to utilize Custom Raster Analysis through a python adapter
- Available support on Desktop app and Server
- Architecture: Module loaded by an adapter - Python-aware and a first-class participant in the function chain.

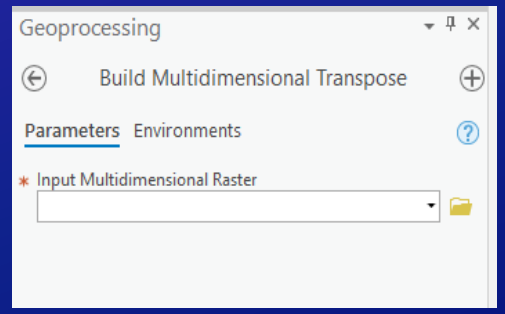


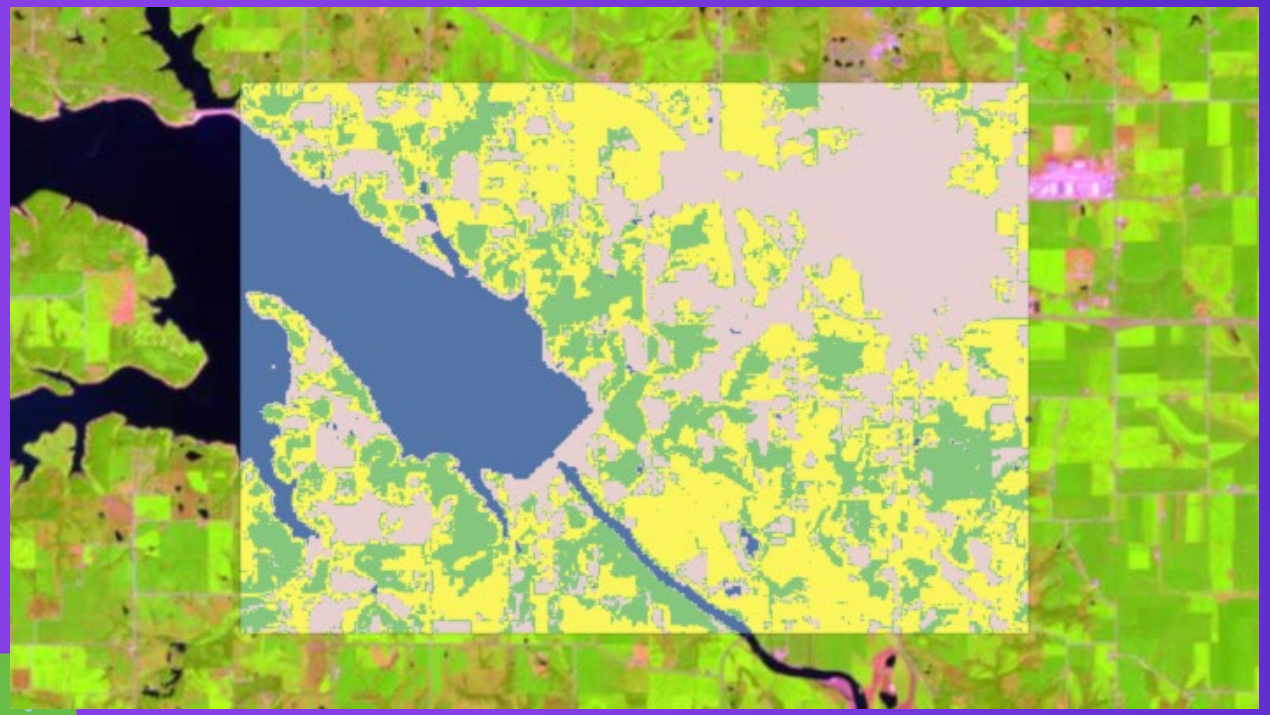
https://github.com/Esri/raster-functions

Cloud Raster Format (CRF)

- Default output imagery format for Raster Analysis tasks
  - Published as “hosted” image service
  - Rendered through Raster Rendering service
  - Support cloud storage and file system
- Tiled Raster Dataset with predefined tiling scheme
- Raster Dataset optimized for Distributed Analysis
  - Parallel Read/Write
  - Local Caching
- Optimized for “fat” Web Client
  - Support accelerated client processing and rendering
- Enhancement for Multidimensional Raster
  - Fast slicing operation
  - Transposed for optimal profiling operation





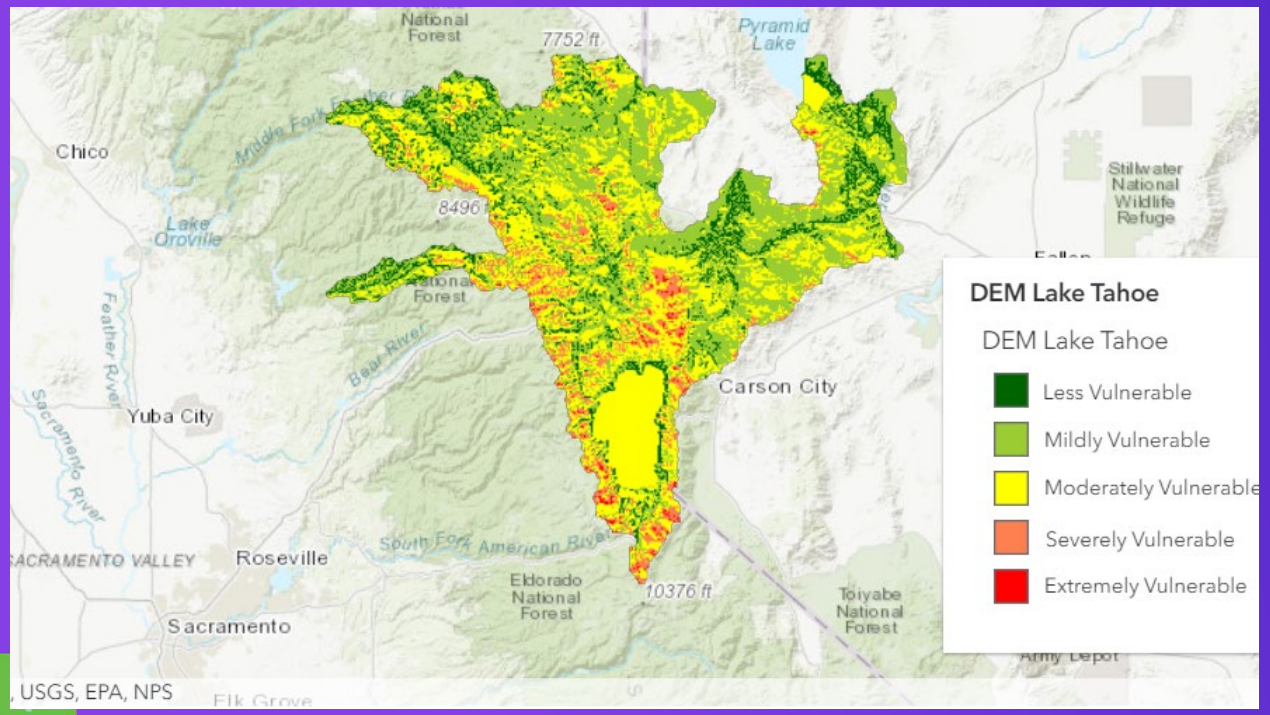


Demo: Image classification

Chunming Peng

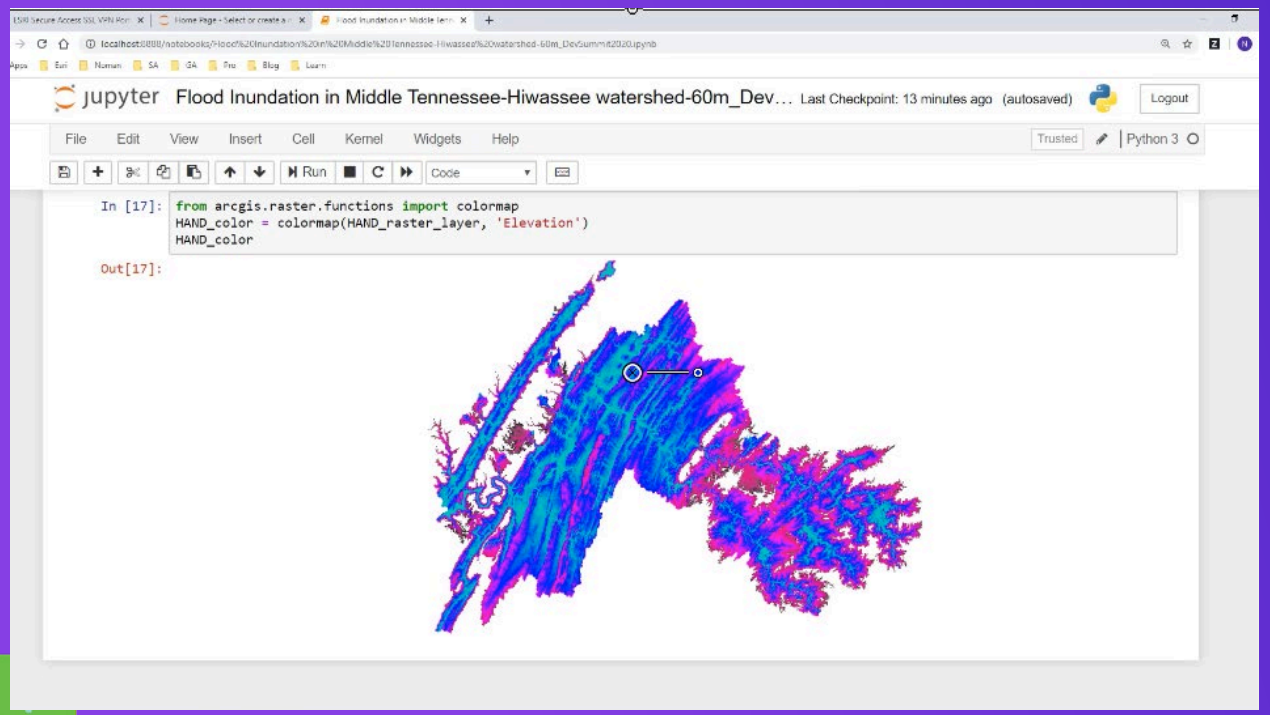
Demo: Orthomapping

Chunming Peng



Demo: Suitability modeling

Atma Mani



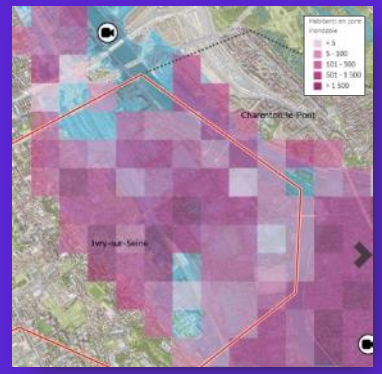
Demo: Hydrology analysis

Nawajish Noman

Conclusion

Applications

Wildfire Risk

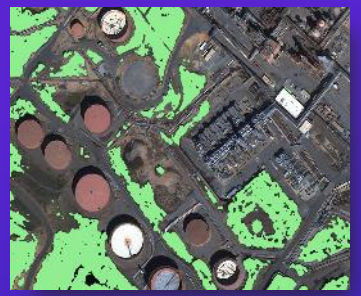


France
Caroviz

Crop Rotation

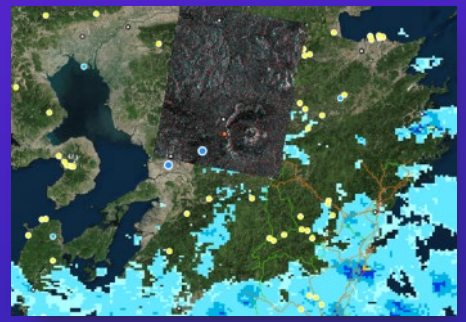
USA

Change Analysis



DigitalGlobe

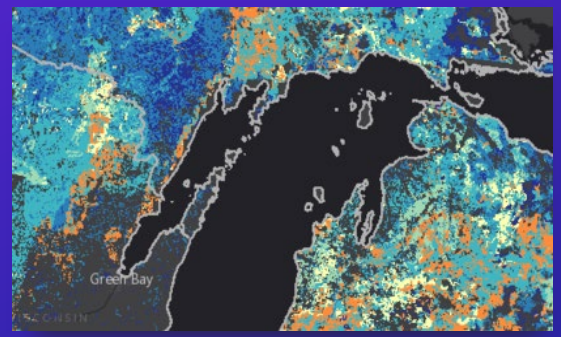
Volcanic Monitoring



Japan
JAXA

Watersheds

Forest Acidification

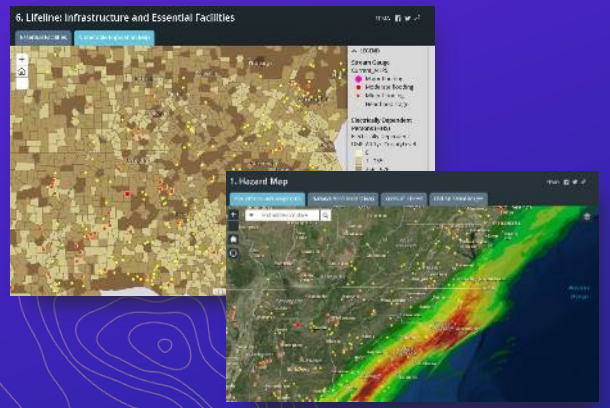


Midwestern US

Effects of Climate Change

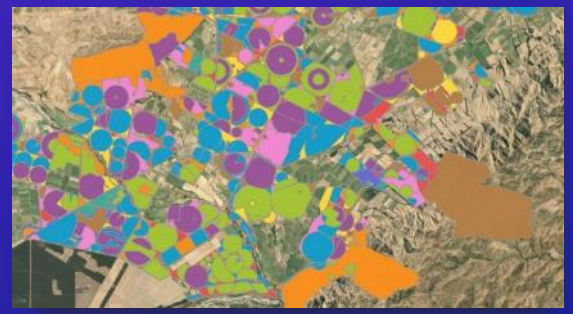
Clark Labs

Assessing Vulnerable Populations



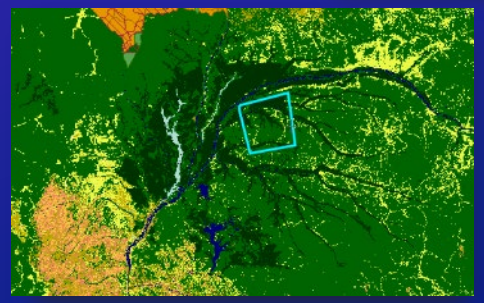
FEMA

Farm Management



New Zealand

Loss of Habitat



Central Africa
Blue Raster

Recap

ArcGIS API for Python – arcgis.raster module

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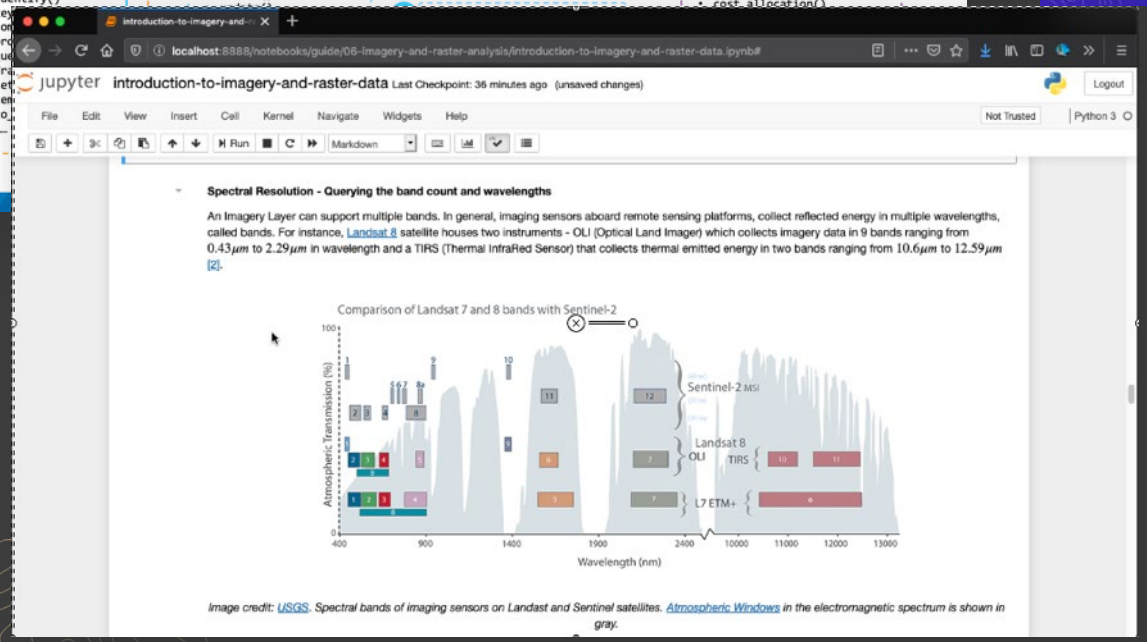

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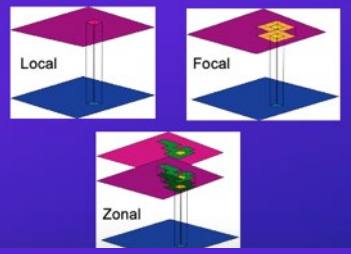

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Analysis: Band Math & Indices
NDVI / NDVI Colorized
SAVI / MSAVI / TSAVI
GEMI
GVI (Landsat TM)
PVI
Tasseled Cap (Kauth-Thomas)
Binary Thresholding
Heat Index
Wind Chill

Statistics
ArgStatistics

Visualization & Appearance
Contrast and Brightness
Convolution
Pansharpening
Resample
Statistics and Histogram
Stretch

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

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
Region Group
Lookup

Interpolation
Interpolate Irregular Data
- Nearest Neighbor
- IDW
- EBK
Swath

Surface Generation & Analysis
Aspect
Curvature
Elevation Void Fill
Hillshade
Shaded Relief
Slope
Contour

Python
Custom Algorithms

Analysis: Image Segmentation & Classification
Segmentation (Mean Shift)
Training (ISO, SVM, ML, Random trees)
Supervised Classification

Analysis: Overlay
Weighted Sum

Statistics:
Zonal Statistics
Cell Statistics
Focal Statistics *

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

Analysis: Distance & Density
Euclidean Distance
Cost Distance
Least Cost Path
Kernel Density
Path Allocation
Path Distance
Corridor
Path Distance backlink

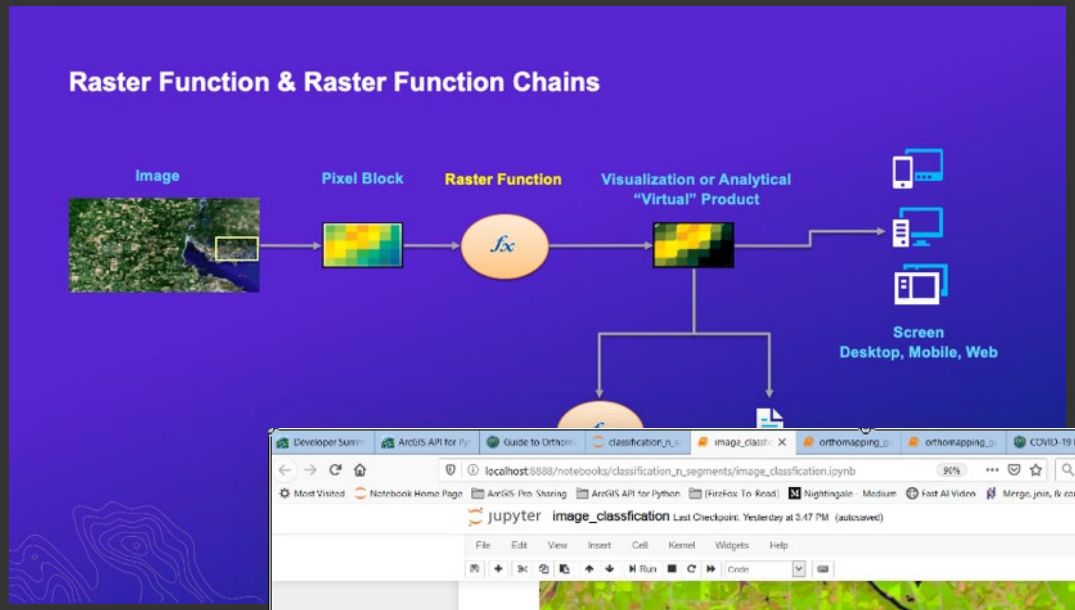
Analysis: Hydrology
Fill
Flow Accumulation
Flow Direction
Flow Distance
Stream Link
Watershed

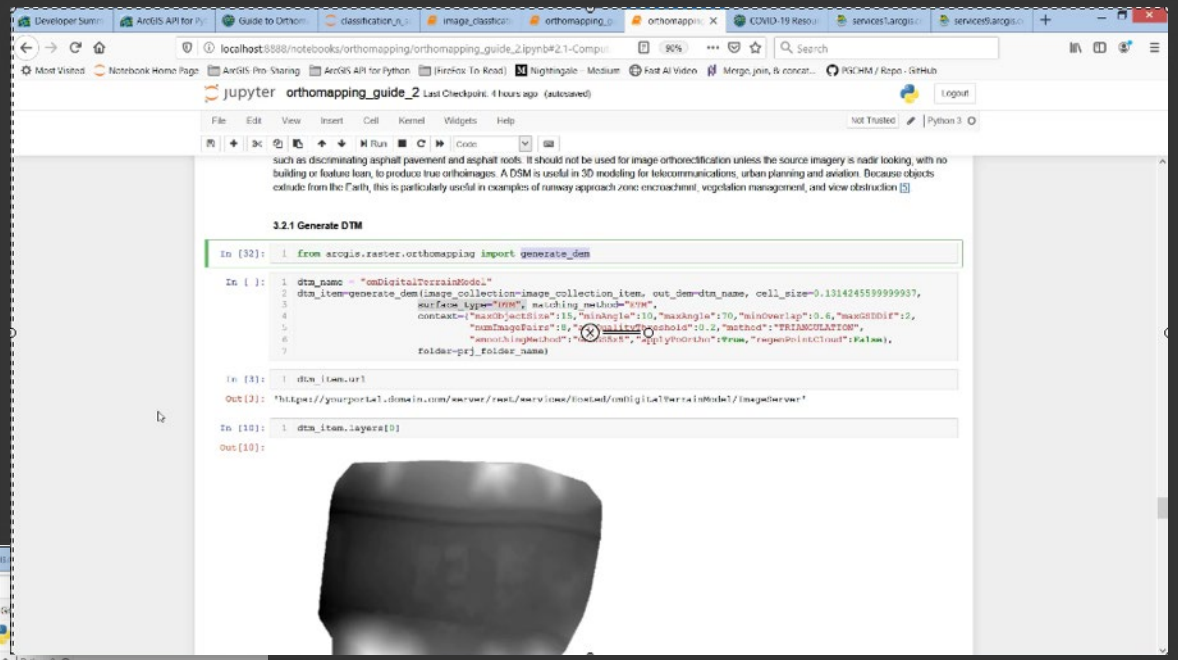
Analysis: Overlay
Weighted Overlay

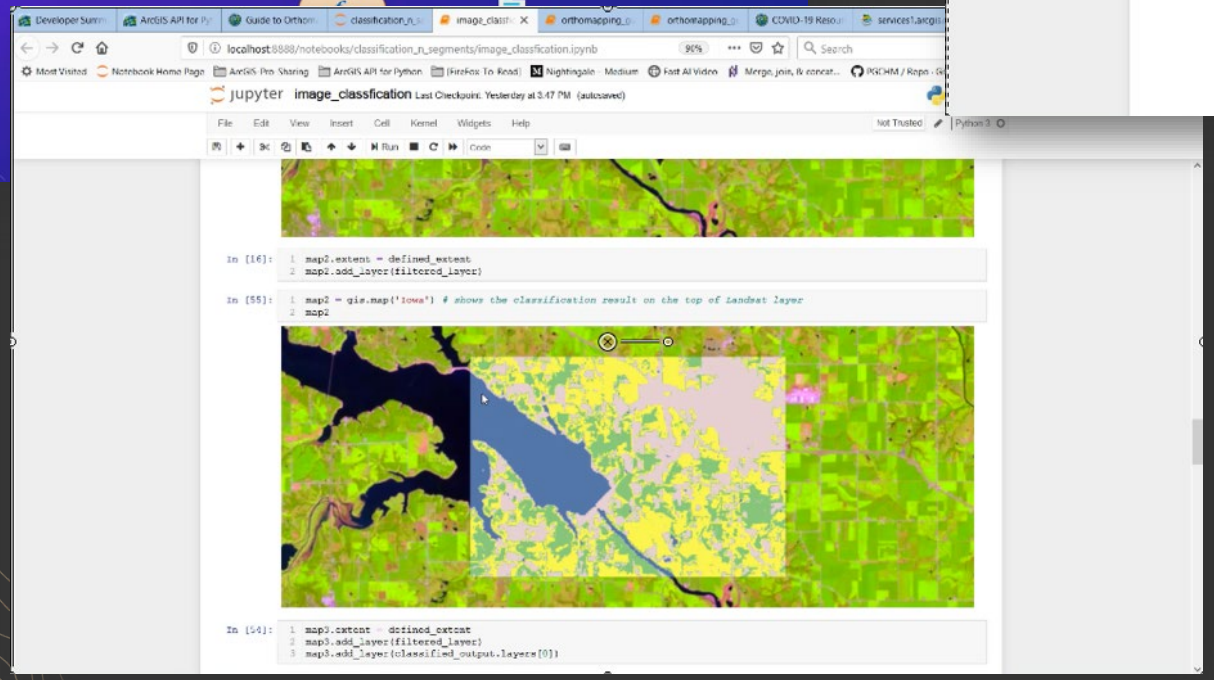
Surface Generation & Analysis
Viewshed

Data Management
Nibble

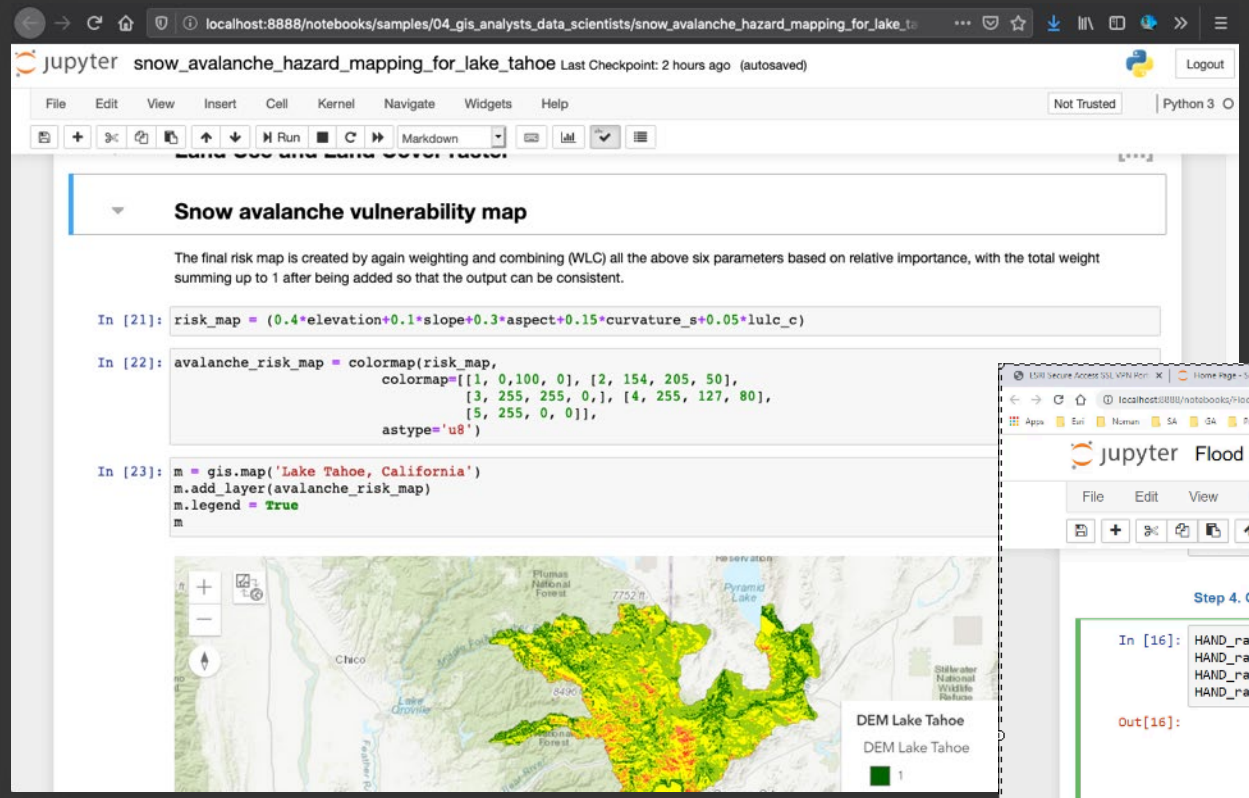
Recap

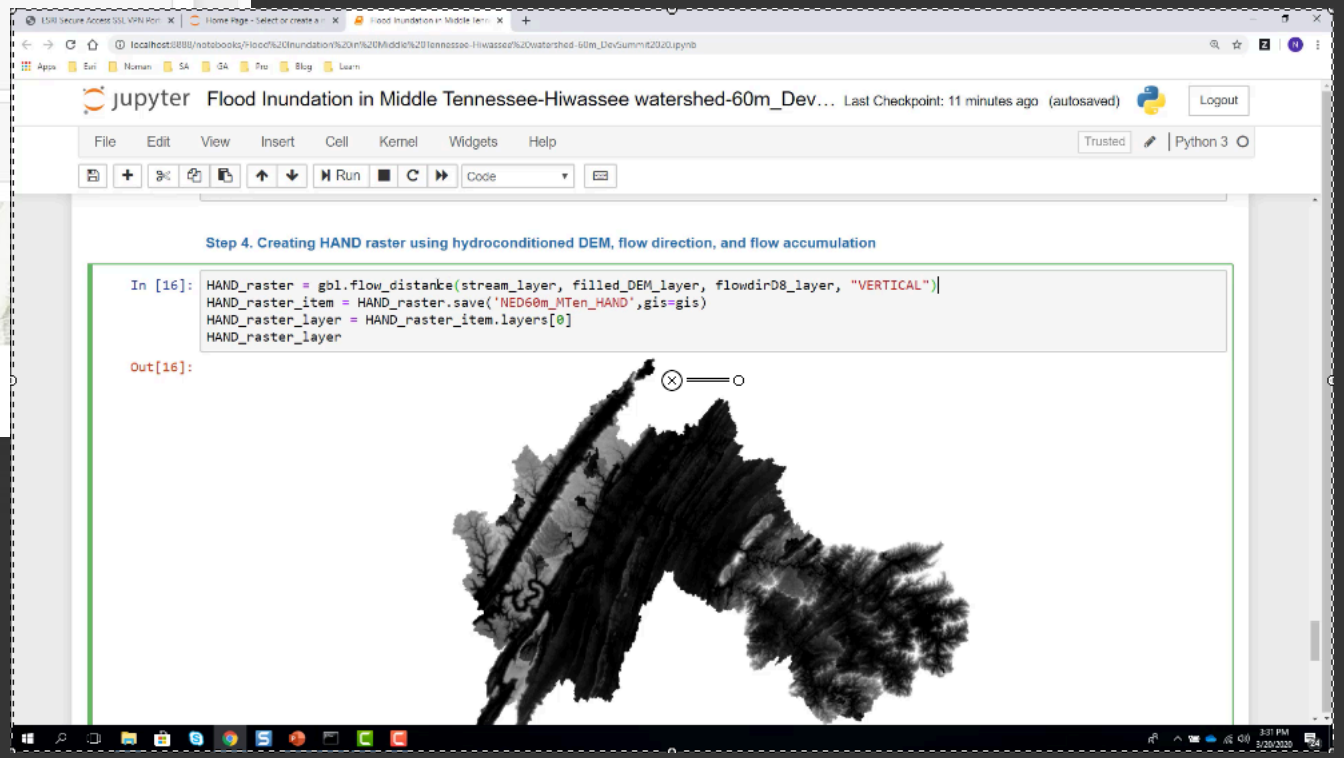

Raster Function & Raster Function Chains
Image
Pixel Block
Raster Function
Visualization or Analytical
"Virtual" Product
Screen
Desktop, Mobile, Web


jupyter orthomapping_guide_2
3.2.1 Generate DTM
from arcgis.raster.orthomapping import generate_dem


jupyter image_classfication
map2.extent = defined_extent
map2.add_layer(filtered_layer)
map2 = gis.map('Iowa') # shows the classification result on the top of Landsat layer
map2
map3.extent = defined_extent
map3.add_layer(filtered_layer)
map3.add_layer(classified_output.layers[0])

Recap


localhost:8888/notebooks/samples/04_gis_analysts_data_scientists/snow_avalanche_hazard_mapping_for_lake_ta
jupyter snow_avalanche_hazard_mapping_for_lake_tahoe Last Checkpoint: 2 hours ago (autosaved)
Logout
File Edit View Insert Cell Kernel Navigate Widgets Help
Not Trusted
Python 3
Run
Markdown
Snow avalanche vulnerability map
The final risk map is created by again weighting and combining (WLC) all the above six parameters based on relative importance, with the total weight summing up to 1 after being added so that the output can be consistent.
In [21]: risk_map = (0.4*elevation+0.1*slope+0.3*aspect+0.15*curvature_s+0.05*lulc_c)
In [22]: avalanche_risk_map = colormap(risk_map,
colormap=[[1, 0,100, 0], [2, 154, 205, 50],
[3, 255, 255, 0,], [4, 255, 127, 80],
[5, 255, 0, 0]],
astype='u8')
In [23]: m = gis.map('Lake Tahoe, California')
m.add_layer(avalanche_risk_map)
m.legend = True
m
Chico
DEM Lake Tahoe
DEM Lake Tahoe
1


jupyter Flood Inundation in Middle Tennessee-Hiwassee watershed-60m_Dev... Last Checkpoint: 11 minutes ago (autosaved)
Logout
File Edit View Insert Cell Kernel Widgets Help
Trusted
Python 3
Run
Code
Step 4. Creating HAND raster using hydroconditioned DEM, flow direction, and flow accumulation
In [16]: HAND_raster = gbl.flow_distance(stream_layer, filled_DEM_layer, flowdirD8_layer, "VERTICAL")
HAND_raster_item = HAND_raster.save('NED60m_MTen_HAND',gis=gis)
HAND_raster_layer = HAND_raster_item.layers[0]
HAND_raster_layer
Out[16]:

Learning resources

- Introduction to the raster module - https://developers.arcgis.com/python/guide/using-imagery-layers/
- Spatial analysis – https://pro.arcgis.com/en/pro-app/help/analysis/spatial-analyst/basics/get-started-with-spatial-analyst-in-arcgis-pro.htm
- Imagery analysis - https://pro.arcgis.com/en/pro-app/help/analysis/image-analyst/what-is-the-arcgis-pro-image-analyst-extension-.htm
- Demo on image classification – https://developers.arcgis.com/python/guide/image-classfication-and-segmentation/
- Demo on orthomapping - https://developers.arcgis.com/python/guide/orthomapping-guide-1/
- Demo on weighted overlay analysis – https://developers.arcgis.com/python/sample-notebooks/snow-avalanche-hazard-mapping-for-lake-tahoe/
- Books – The Esri Guide to GIS Analysis – Volume 2, 3