Esri Developer Summit
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Writing Image Processing Algorithms using the Python Raster Function

Gregory Brunner Jamie Drisdelle Feroz Abdul Kadar

Agenda

- Introduction
- Anatomy of a raster function
- Building raster models
- Additional considerations
- Q&A

Introduction

Raster Functions

What's a Raster Function?

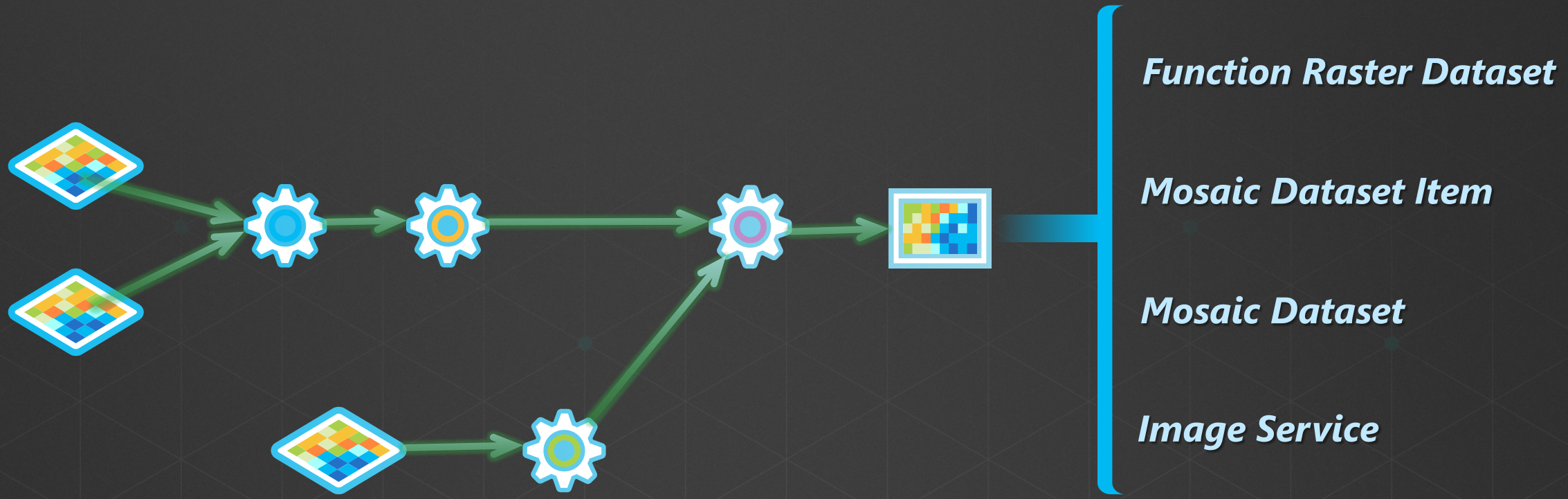
The Fundamentals

- Mapping of one raster to another.
- Loosely, $I : \mathbb{N}^3 \rightarrow \mathbb{R}$ $F : (I, \Phi) \rightarrow \mathbb{R}$
- On-demand. Transient.
- Different from a geoprocessing tool.

*... a **transformation** of one raster into another.*

Chaining Raster Functions

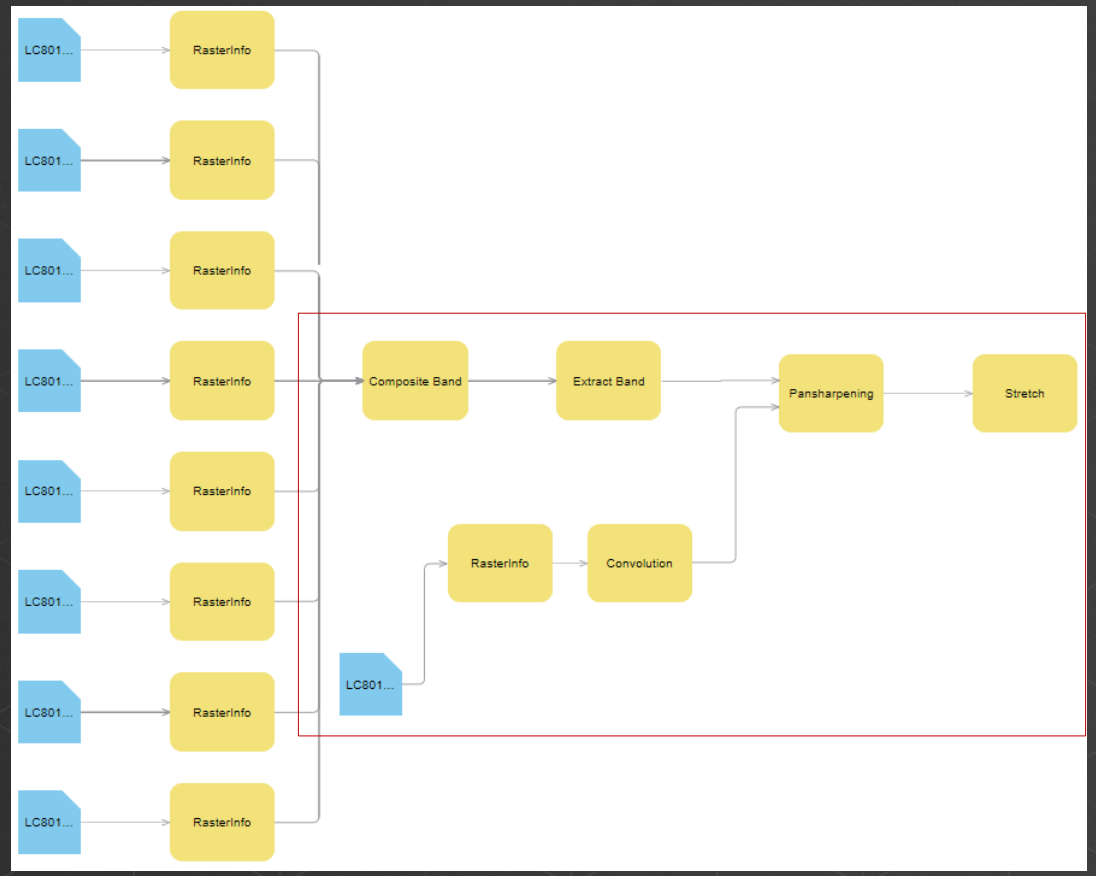
Raster Model

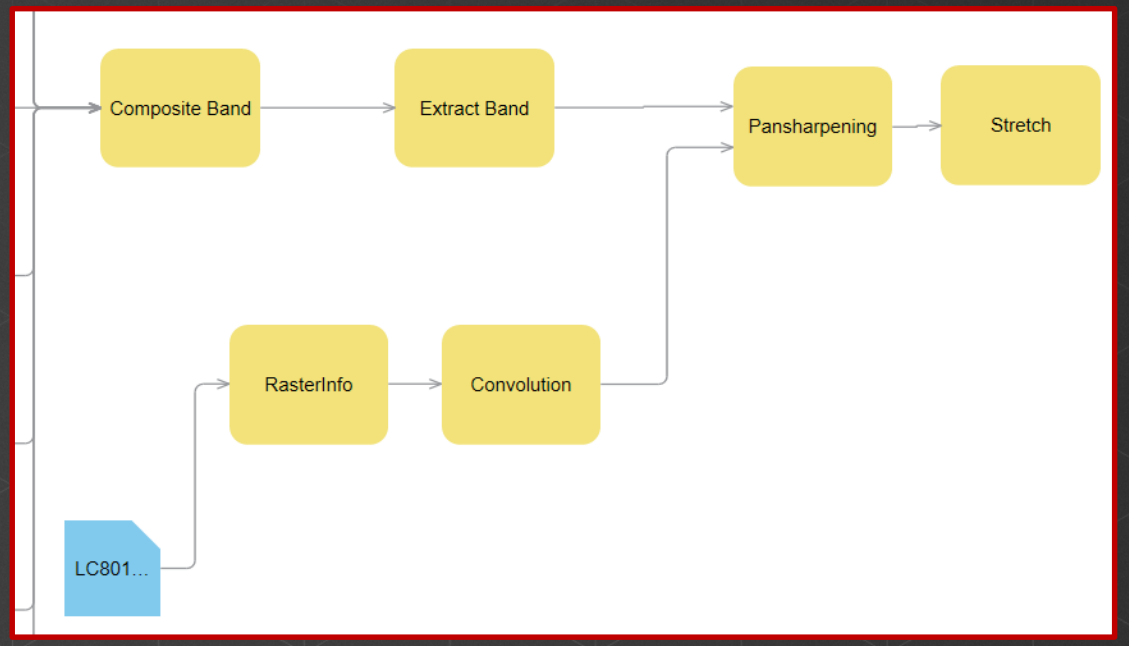


*A **raster model** encapsulates your algorithm as a tree of functions.*

Chaining Raster Functions

An example: Landsat 8 Pansharpened





Demo

Apply a **raster functions** to image layers in ArcMap

Browsing **raster models** on an image service in ArcGIS.com

Python Raster Functions

What's a *Python* Raster Function?

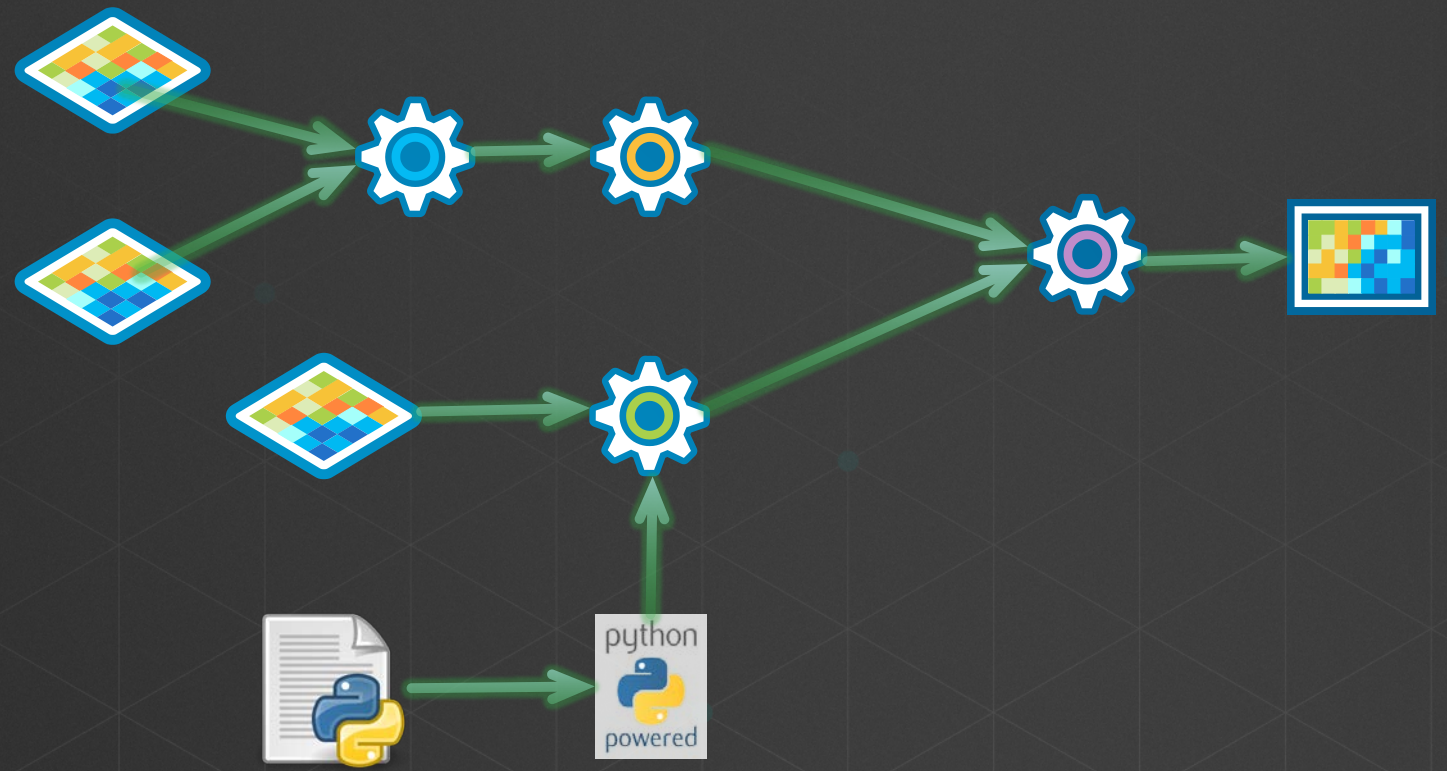
The Extended Model

- Transforming rasters—image processing and analytic algorithms—in Python.
- Implement a raster function from the comfort of your *Python module*.
- *Architecture:* Module loaded by an adapter—Python-aware *and* a first-class participant in the function chain.

Your Python module—assisted by ArcGIS—is a raster function.

What's a *Python* Raster Function?

The Extended Model



Function Raster Dataset

Mosaic Dataset Item

Mosaic Dataset

Image Service

Motivation

Why Raster Functions in Python?

- Extend ArcGIS—participate in a *raster model.*
- Primary pipeline for image data in ArcGIS—*processing*, *analyzing*, and *visualizing*.
- On-the-fly at display resolution, or in batch at full resolution.
- Portable. Reusable. Dynamic. Fast. Scalable.
- **Why Python?**
  - Friendly & easy to learn. “readability first”. “batteries included”.
  - Huge collection of libraries. Vibrant community of *Pythonistas* and *Pythoneers*.
  - “…de facto ***superglue*** language for ***modern scientific computing***.”
  - “…tools for almost every aspect of scientific computing are *readily available* in Python.”

The API

How do I create Raster Function in Python?

- How does ArcGIS Desktop or Server *interact* with my raster function?
  - Get started—step-by-step guide
  - Real-world or reference implementations—excellent springboard
  - Well-documented API reference

- What additional libraries are needed? How complicated is it?
  - Lightweight design—no external dependencies outside of NumPy to begin with.
  - ArcGIS' *adapter* provides assistance—opt out to take control of specific aspects.

*Create a new raster function using **simple** and **familiar Pythonesque** constructs.*

Hello, World!

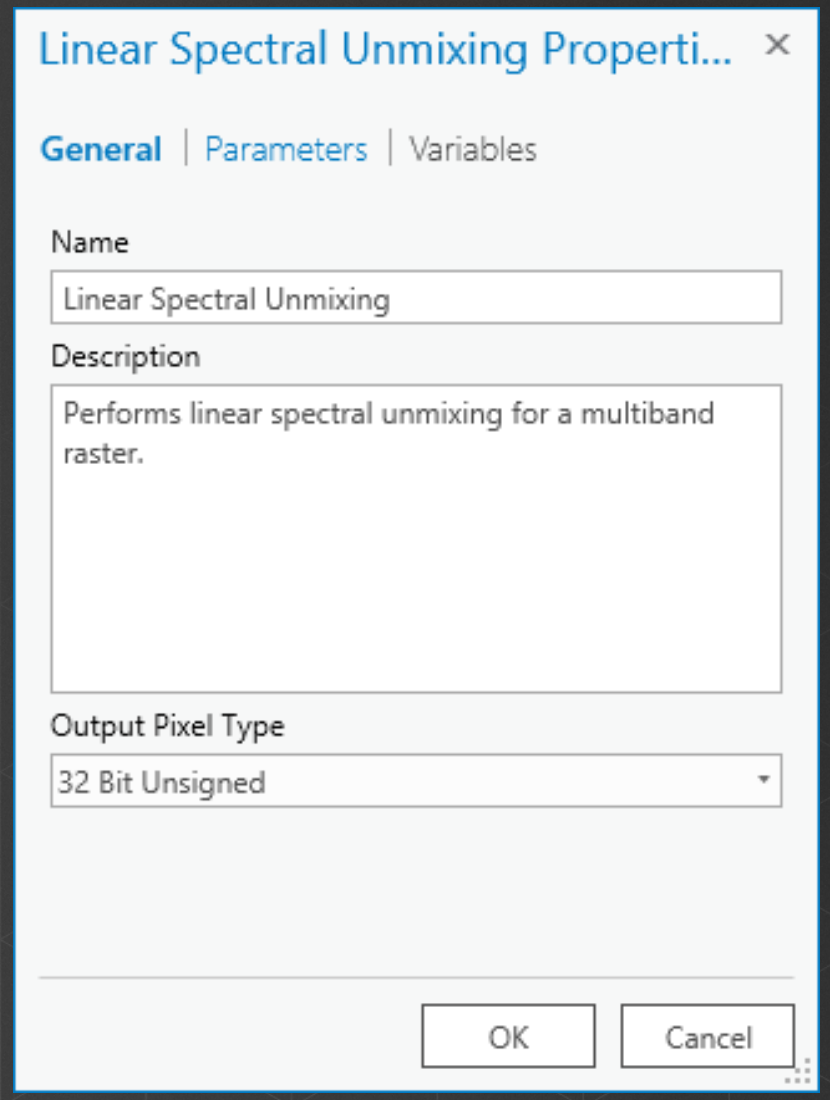
```python
import numpy as np

class HelloWorld():
    def __init__(self):
        self.name = "Hello World Function"

    def getParameterInfo(self):
        return [{
            'name': 'r',
            'dataType': 'raster'
        }]

    def updatePixels(self, tlc, shape, props, **pixelBlocks):
        r = pixelBlocks['r_pixels'] + 10
        pixelBlocks['output_pixels'] = r.astype(props['pixelType'])
        return pixelBlocks
```

The API

`__init__`

- customize our function object—a specific instance of our class—as soon as it's created.

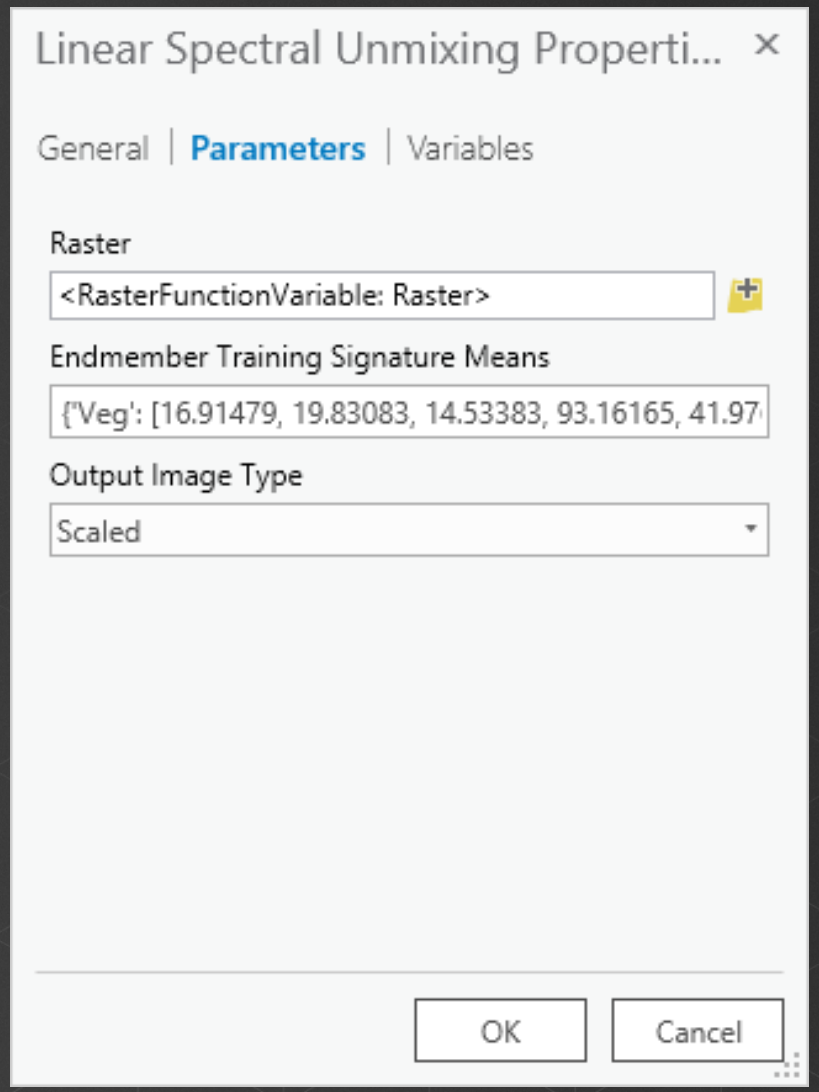
- Define raster function *name* & *description.*



The API

`getParameterInfo()`

- Define all *input parameters* to the function.
- For each parameter, define:
  - Name (Identifier)
  - Display Name
  - Long Description
  - Data Type
  - Default Value
  - Required vs Optional
  - ...



The API

`getConfiguration()`

- How are input rasters read—Padding, Mask, …?
- How's the output raster constructed—inherit NoData, Metadata, …?
- ***Given:*** scalar (non-raster) values.
- ***Returns:*** dictionary containing configuration attribute values.

The API

`selectRasters()`

- Define a subset of input rasters.
- Pixels read from *selected* rasters.
- **Given:** properties of the requested pixel block, all scalar parameter values.
- ***Returns:*** names of selected rasters.

The API

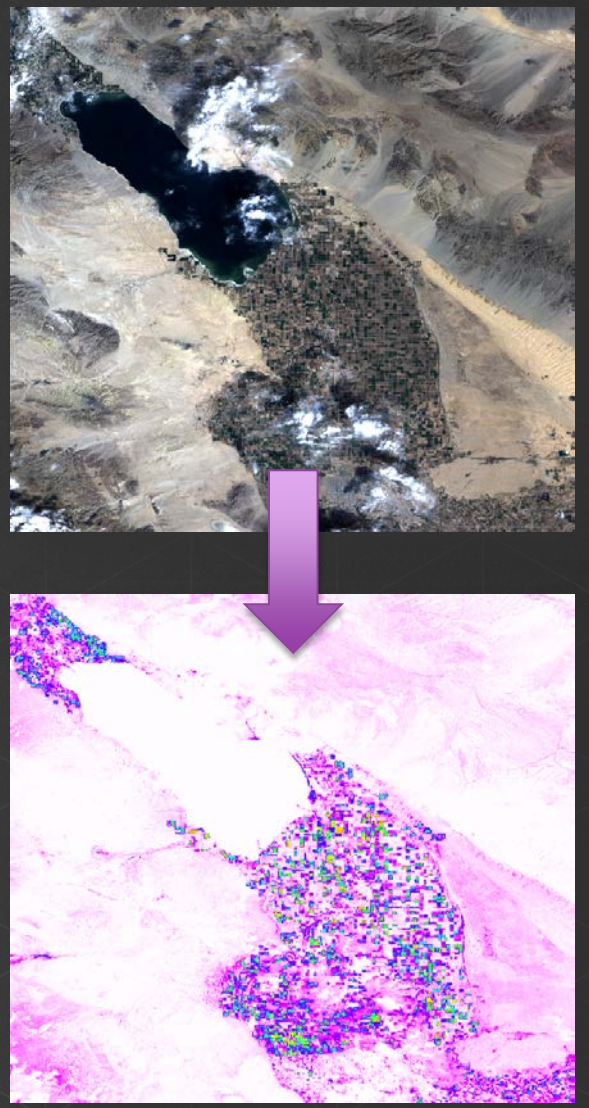
`updateRasterInfo()`

- Defines the output raster.
- Invoked each time a dataset containing the Python raster function is initialized.
- ***Given:*** Raster info associated with all input rasters.
- ***Returns:*** *Raster Info* of the output raster.

The API

`updatePixels()`

- Workhorse of the raster function. Process Pixels.
- ***Given:***
  - Expected pixel-block size+location
  - output raster properties (map space)
  - pixels+mask of selected input rasters
- ***Returns:*** Pixels+mask of requested pixel block.



The API

`updateKeyMetadata()`

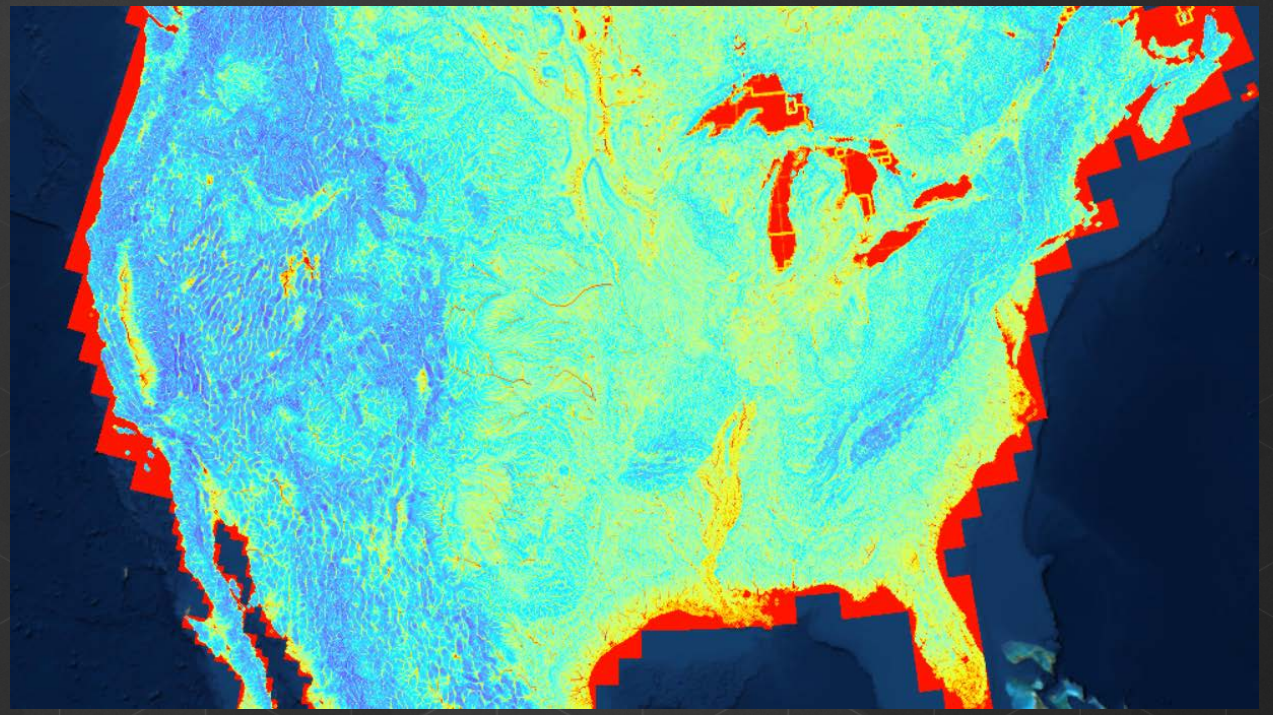
- Create or update dataset- or band-level metadata.
- ***Given:***
  - property names
  - band index
  - current key metadata values
- ***Returns:*** updated values of given properties

The API

`isLicensed()`

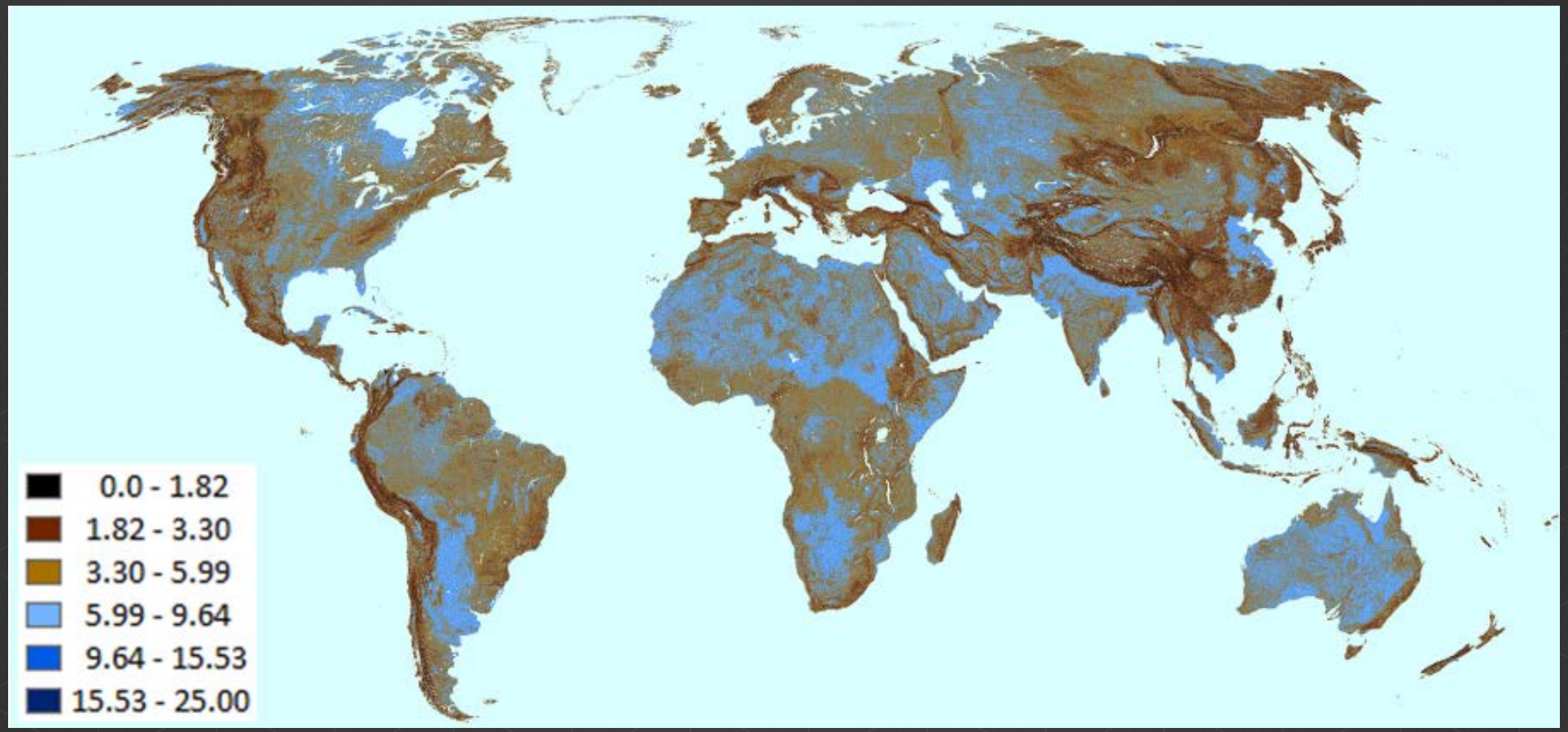
- ***Given:***
  - info on parent product,
  - context of execution.
- ***Returns:***
  - OK to Run (Boolean)—Licensed to execute or not?
  - Expected product level and extension.

Compound Topographic Index



Compound Topographic Index (CTI)

A steady state wetness index, a.k.a. Topographic Wetness index (TWI)



T.R. Matthews et al. 2015

Compound Topographic Index (CTI)

Motivation

- There's a need in the agricultural and natural resources community
- To explore Python Raster Functions
- To understand the limits of a Python Raster Function
  - Can I use *SciPy*?
  - Does it make sense to use *for* loops?
  - How does a Python raster function *chain* with other raster functions?

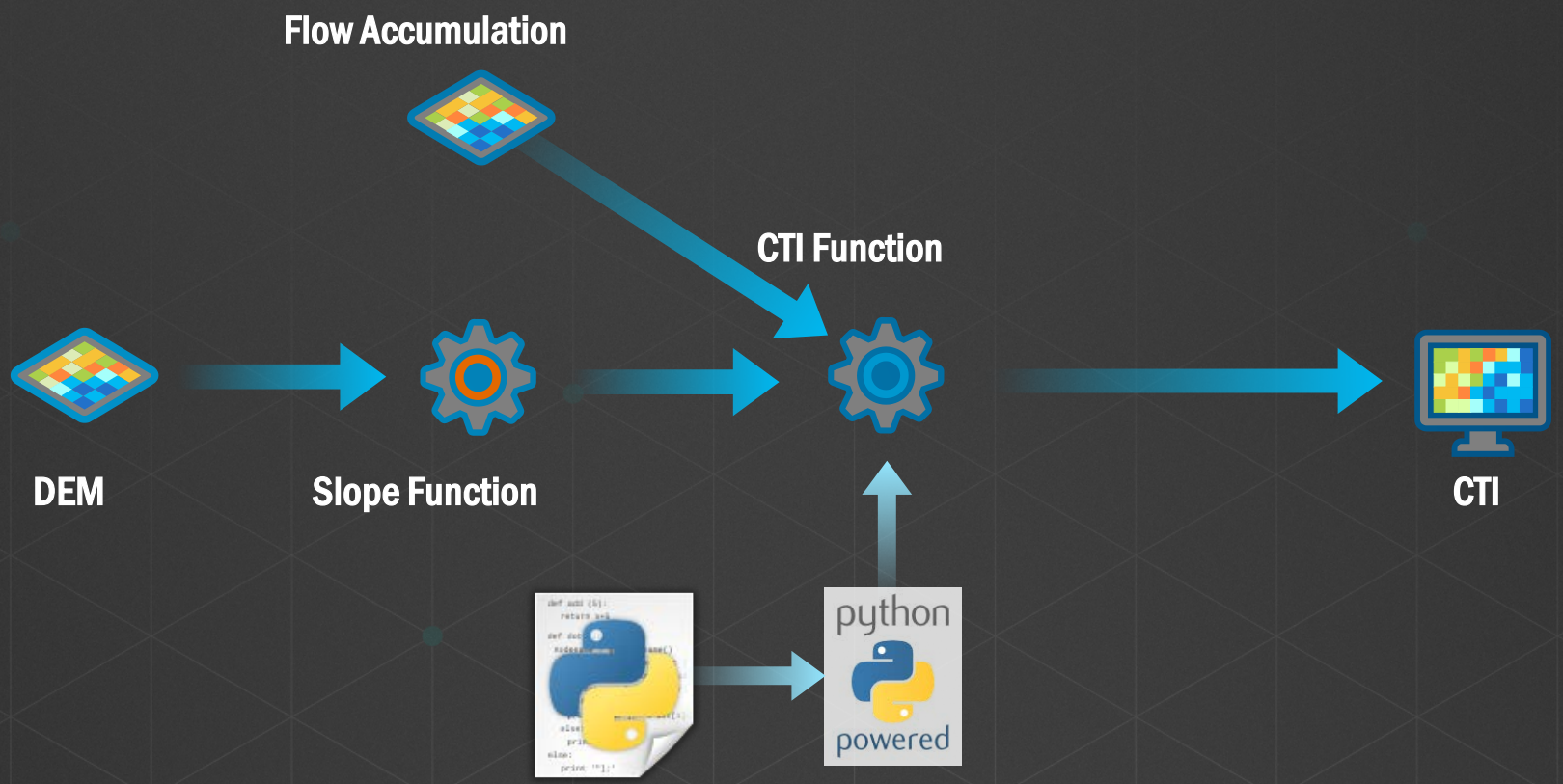
Compound Topographic Index

Calculations

$$CTI = \ln\left((flow_{accumulation} + 1) * \frac{cellsize}{\tan(slope)}\right)$$

Compound Topographic Index

Calculations



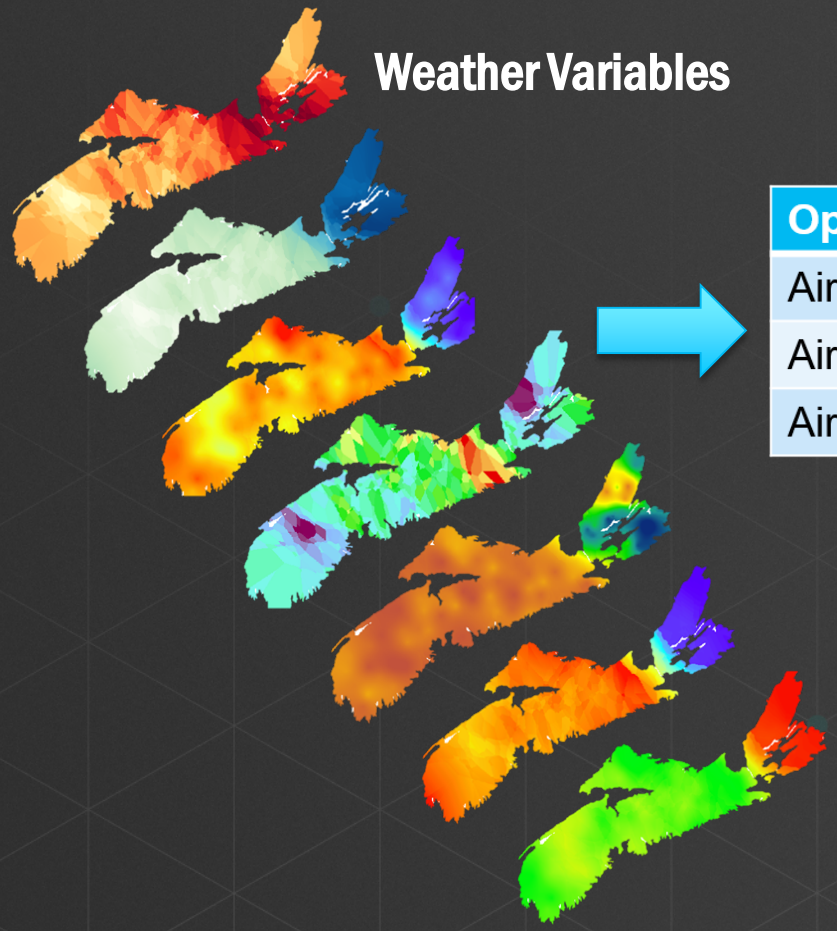
CTI: Code

```
c_slope(slope_deg):
pe = slope_deg * pi/180 #np.arctan
urn slope

c_cti(slope, flow_acc, cellsize):
_slope = np.tan(slope)
_slope[tan_slope==0]=0.0001
 = np.log(((flow_acc+1)*cellsize)/
urn cti
```

Site Suitability Analysis

Site Suitability Analysis

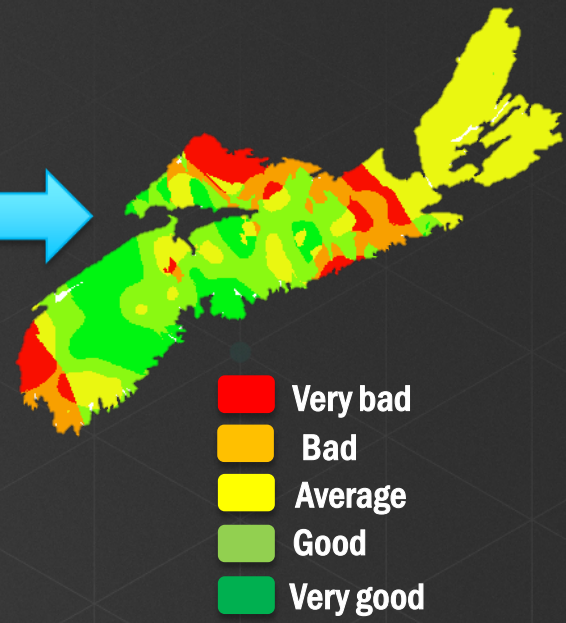
Weather Variables



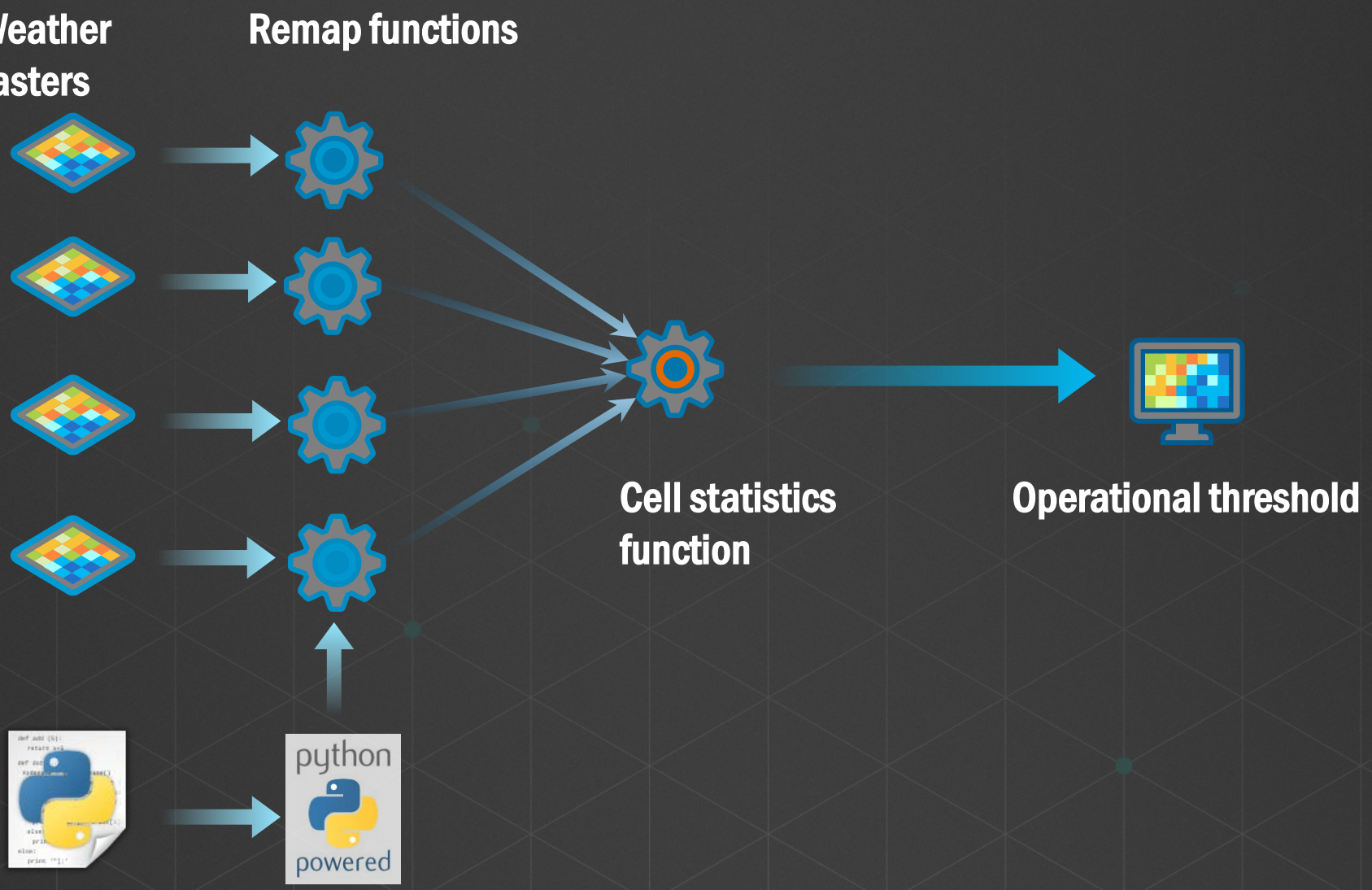
Remap Table

Operation	Variable	From	To	Remap
Air Defense	Temperature	50	100	-2
Air Defense	Cloud Ceiling	2460	4920	-1
Air Defense	Wind speed	0	36	0

Output Function Raster



Site Suitability Analysis



Site Suitability Analysis

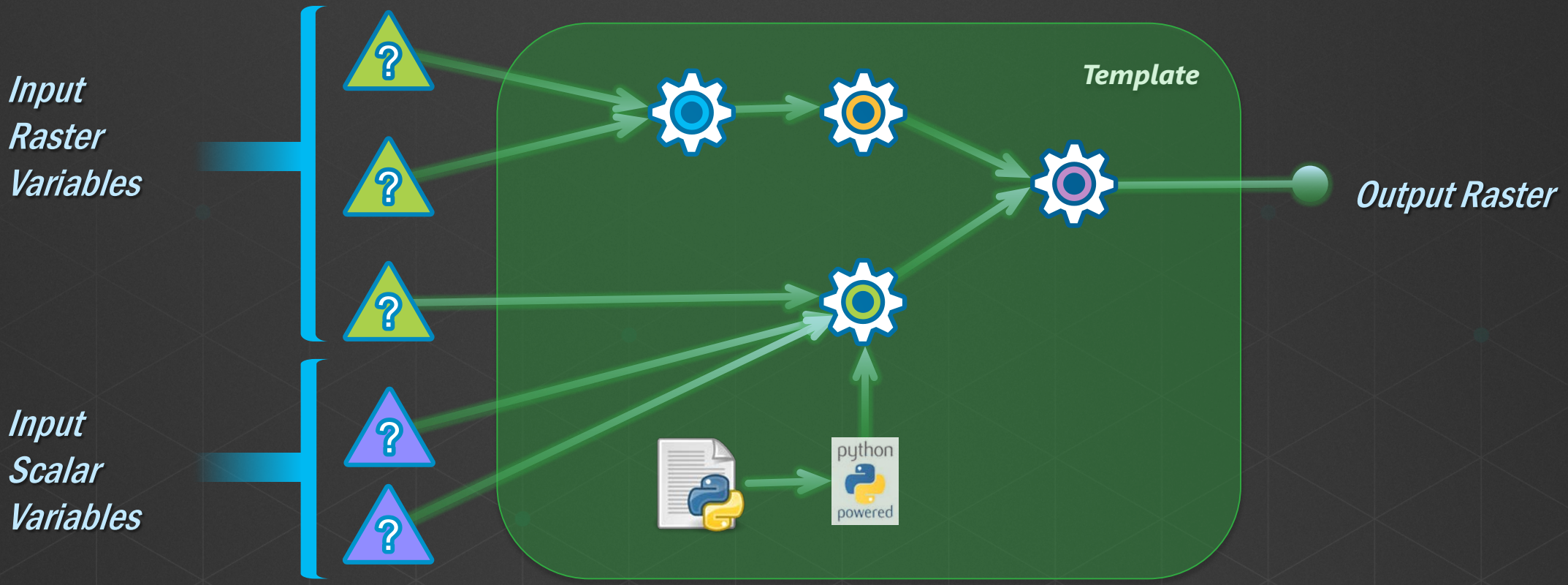
```
# use zonal thresholds to update output pixels...
if ZT is not None and len(ZT.keys()):
    for k in (zoneIds if zoneIds is not None else [None]):
        T = ZT.get(k, None)         # k from z might not be in ztMap
        if not T:
            continue

        for t in T:
            I = (z == k) if z is not None else np.ones(v.shape, dtype=bool)
            if t[0] and t[1]:       # min and max are both available
                I = I & (v > t[0]) & (v < t[1])
            elif t[0]:
                I = I & (v > t[0])
            elif t[1]:
                I = I & (v < t[1])
            p[I] = (t[2] if t[2] is not None else self.defaultTarget)

pixelBlocks['output_pixels'] = p
```

Building *Raster Models*

Templatized chains of raster functions

What's a Raster Model?

The basic concept



*A templatized raster model replaces one or more inputs with place-holder **Variables.***

Raster Model

Basic workflows with “function template”

- Create new function templates
  - Via *Raster Function Template Editor*
  - Layer > Symbology > Export As Raster Function Template
  - Function Raster Dataset > Functions > Save as

- *Raster Layer* in a Map
  - Image Analysis Window
  - Raster Functions Pane in *Pro*
  - Layer > Properties > Functions tab

*A raster function template makes your processing or analysis **portable**.*

Raster Model

Advanced workflows with function templates

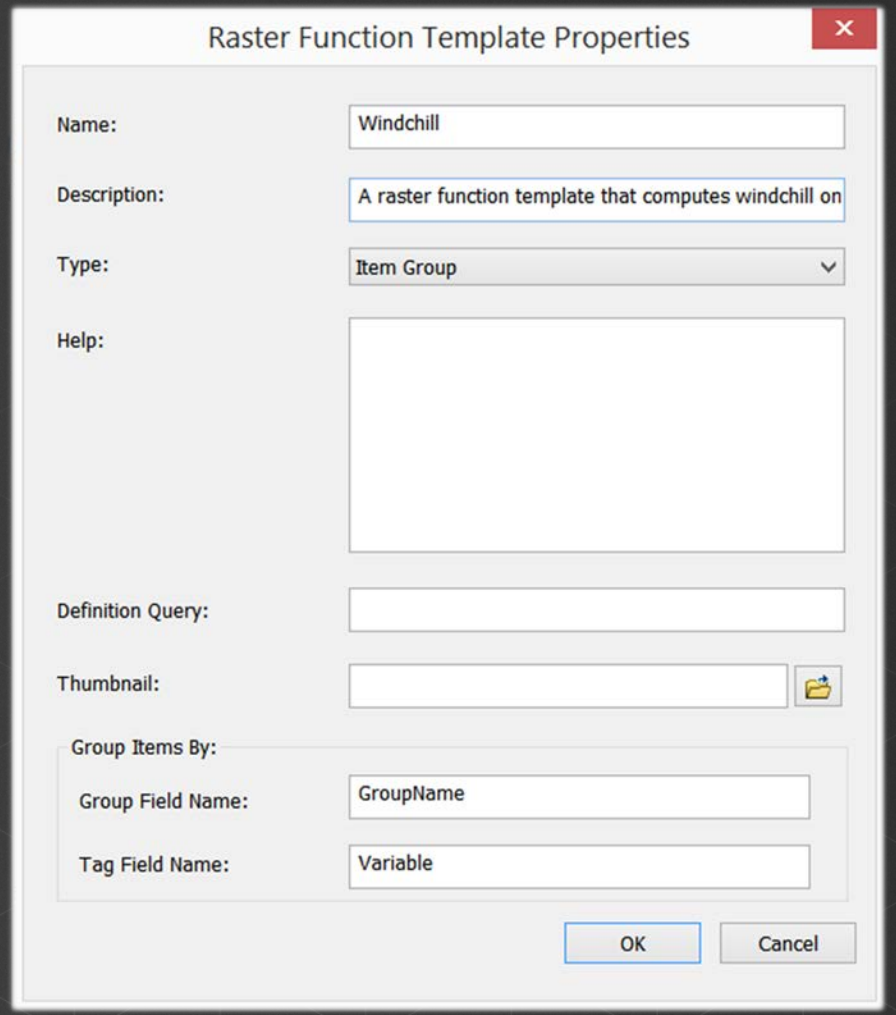
- On a Mosaic Dataset
  - Populating a mosaic using the Add Rasters tool
  - Mosaic dataset items
    - *Batch Edit Raster Functions or*
    - *Edit Raster Function* Geoprocessing Tool.
  - As *Processing Templates*
- On an Image Service—for server-side processing

Learn more at https://github.com/Esri/raster-functions#raster-function-templates.

Raster Model

Properties of a function template

- Name & Description
- Type: *Item*, *Group*, or *Mosaic.*
- Definition Query
- *Fields* that control *grouping*.



Demo

Apply *CTI* raster model to image layers on map using ArcGIS Pro

Demo

Apply *suitability* raster model to a mosaic dataset using ArcMap

Browse processing templates of the mosaic layer

Additional Considerations

Performance

- Vectorize.
- Use NumPy and SciPy.
- Use *Cython:* For production-grade performance.
- Bridge to C/C++ implementations via *ctypes* or *Boost.Python.*

Leverage well-known options to optimize time-critical parts of your raster function.

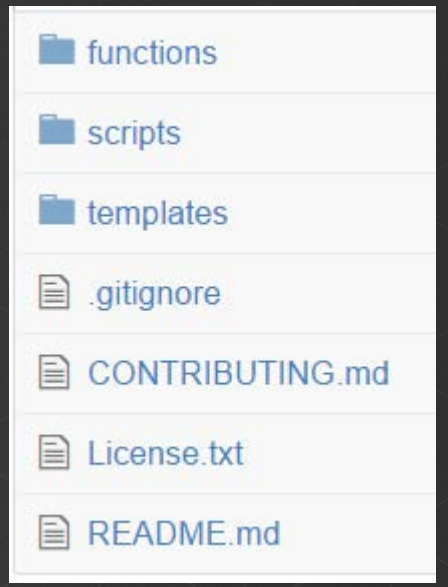
Publishing & Deployment

- Python version
  - Desktop *vs.* Pro: Python 2.7 *vs.* 3.4
  - Desktop *vs.* Server: 32- *vs.* 64-bit Python 2.7
- Package dependencies
- Binary deployment
  - CPython bytecode. Cython compiled binary.
  - *isLicensed* method to restrict usage.

GitHub

Where do functions and templates live?

- https://github.com/Esri/*raster-functions*
- Curated collection of raster *functions* and *templates.*
- Go ahead:
  - Browse samples to learn more.
  - *Fork* the repo. Experiment.
  - Log defects or enhancement requests as *issues*.
  - Send *pull requests* to contribute code.



GitHub enables collaboration.

Wiki

Where do I find the story?

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

- Details of interaction between ArcGIS and your Python raster function.

- Recommendations and techniques for writing effective raster functions

- **Anatomy of a Python Raster Function**
  - getParameterInfo
  - getConfiguration
  - updateRasterInfo
  - selectRasters
  - updatePixels
  - updateKeyMetadata
  - isLicensed
- **Writing Effective Raster Functions**
  - Performance Considerations
  - Handling NoData
  - Key Metadata
  - Aggregation and Grouping
  - Using Cython
  - Debugging
  - Deployment

In Closing

- Powerful pipeline for processing, analysis, and visualization.
  - *Raster models* built using *raster functions* for on-demand processing.
  - Fast. Scalable. Integrated. Extensible.
  - Build dynamically derived information products.
  - Manage redundancy, provenance/authenticity, reproducibility.
- Using simple constructs in Python: participate and exploit.
- Code and docs are on *GitHub.*
- We'll help you along the way—@gbrunner, @jdrisdelle, and @akferoz.

Questions?

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Sessions on related topics:

Change Detection using the Python Raster Function*—*Tuesday at 1:00

Getting Started with the JS API for Multidimensional Image Services*—*Tuesday at 1:00

Automating Image Management and Dissemination using Python*—*Wednesday at 10:30

Developing Applications which use Oblique Imagery in ArcGIS*—*Wednesday at 4:00

Getting Started with Imagery using the Web AppBuilder for ArcGIS*—*Wednesday at 4:35

http://www.esri.com/events/devsummit/agenda/detailed-agenda


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