Spatial Data Science in ArcGIS: The Ecosystem

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2021 ESRI DEVELOPER SUMMIT

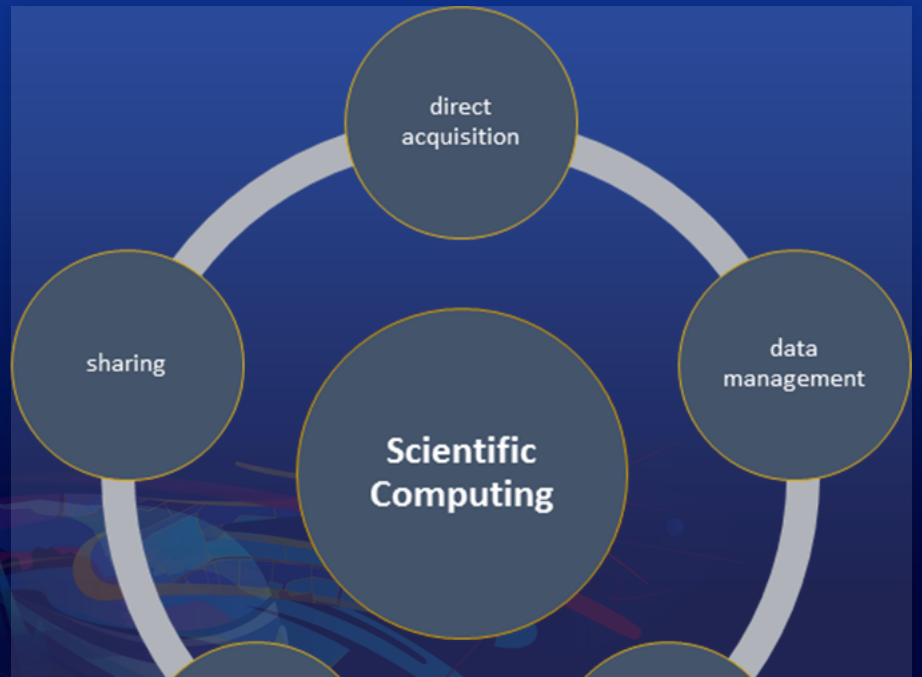
https://github.com/scw/ds-scipy-devsummit-2021-talk

High Quality PDF (5MB)

Resources Section

Data Science

Data Science



The application of computational methods to all aspects of the process of scientific investigation – data acquisition, data

ArcGIS for *spatial* data science

- ArcGIS is a *system of record*. Combine data and analysis from many fields and into a common environment.
- Why extend? Can't do it all, we support over 1600 GP tools — enabling *integration* with other environments to extend the platform.
- ArcGIS is an ecosystem that lends itself very nicely

What's in the Ecosystem

Python in ArcGIS

- Python API for driving ArcGIS Desktop and Server
- A fully integrated module: `import arcpy`
- Interactive Window, Python Addins, Python Tooboxes
- ArcGIS API for Python
- *Hosted Notebooks*
- Notebooks in ArcGIS Pro

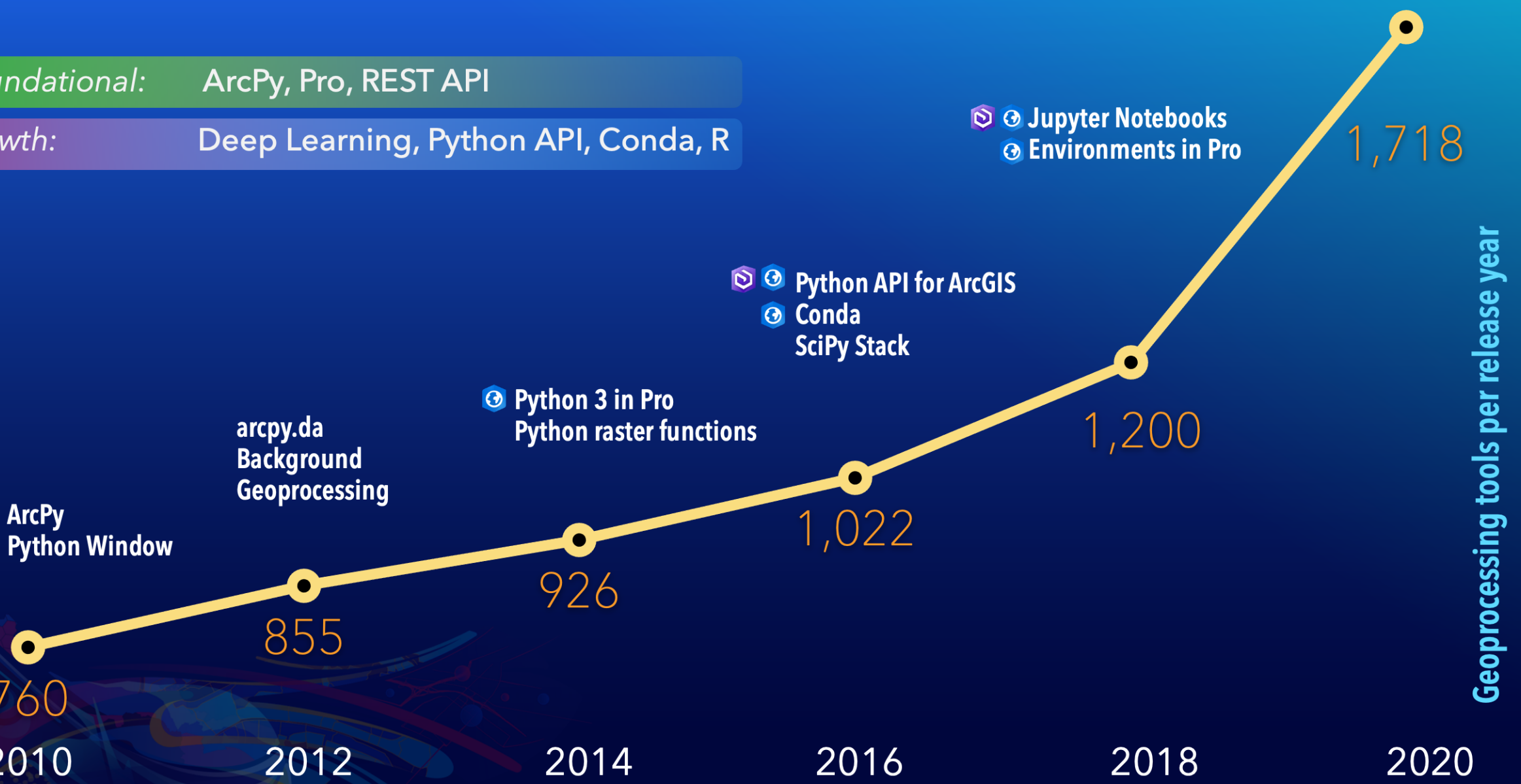
Python Everywhere

ANACONDA

The Growth of Python in ArcGIS

Foundational: ArcPy, Pro, REST API

Growth: Deep Learning, Python API, Conda, R



ArcGIS Python Libraries

ArcPy

- Maps and projects
- Deep access to Pro with simple code
- 1700+ geoprocessing tools

Comprehensive and powerful library for spatial analysis, data management, and conversion.

ArcPy + ArcGIS API for Python

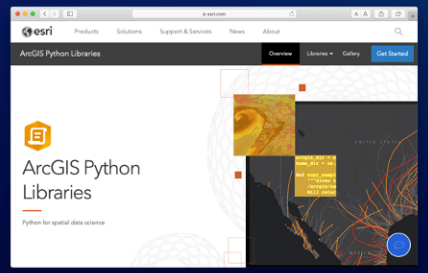
- Do everything with Python
- Jupyter Notebook rich integration
- Seamlessly blend web layers and local analysis

Pro Enterprise Cloud

ArcGIS API for Python

- Manage web layers, maps, and tools
- Deploy anywhere
- Build geospatial deep learning models

Lightweight library for analyzing spatial data, managing your Web GIS, and performing spatial data science.



https://www.esri.com/pythonlibraries

Demo: Notebooks in Pro

Core Python Libraries

Why SciPy?

- Most languages don’t support things useful for science, e.g.:
  - Vector primitives
  - Complex numbers
  - Statistics
- Object oriented programming isn’t always the right paradigm for analysis applications, but is the only

Included SciPy

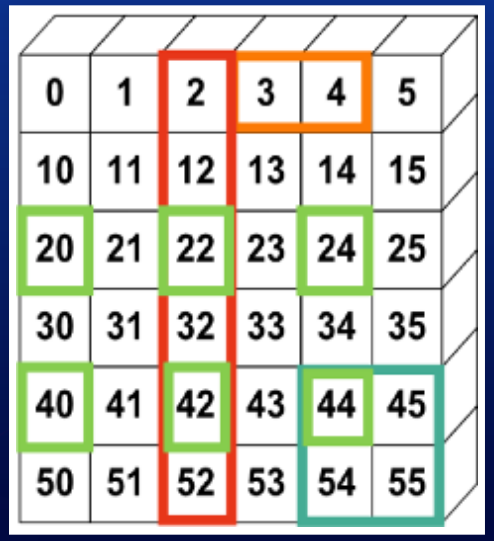
Package	KLOC	Contributors	Stars
dask	52	229	4293
IPython	36	587	13408
JupyterLab	85	214	7396
NumPy	236	738	9868
Pandas	183	1433	18431
SciPy	387	699	5522
SymPy	243	730	5617

- Plotting library and API for NumPy data
- Matplotlib Gallery
- Pro *also* includes `arcpy.chart` for plotting via Pro charts
- Embedded Pro charts in notebooks

ArcGIS with NumPy

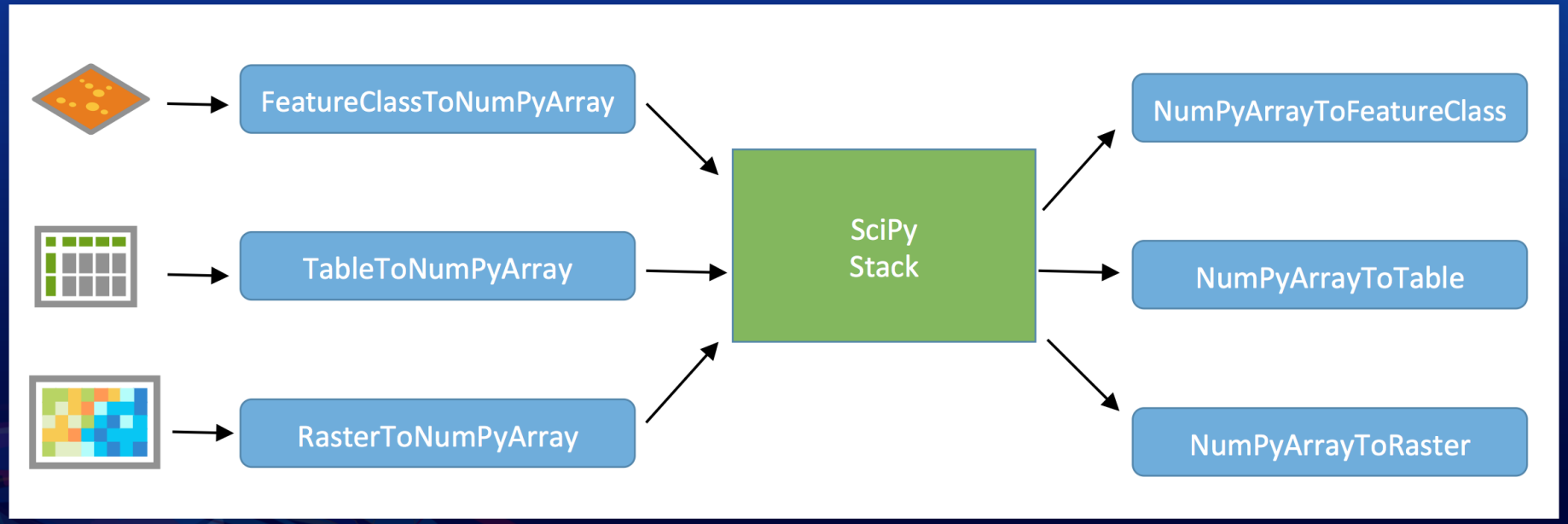
NumPy

1. An array object of arbitrary homogeneous items
2. Fast mathematical operations over arrays



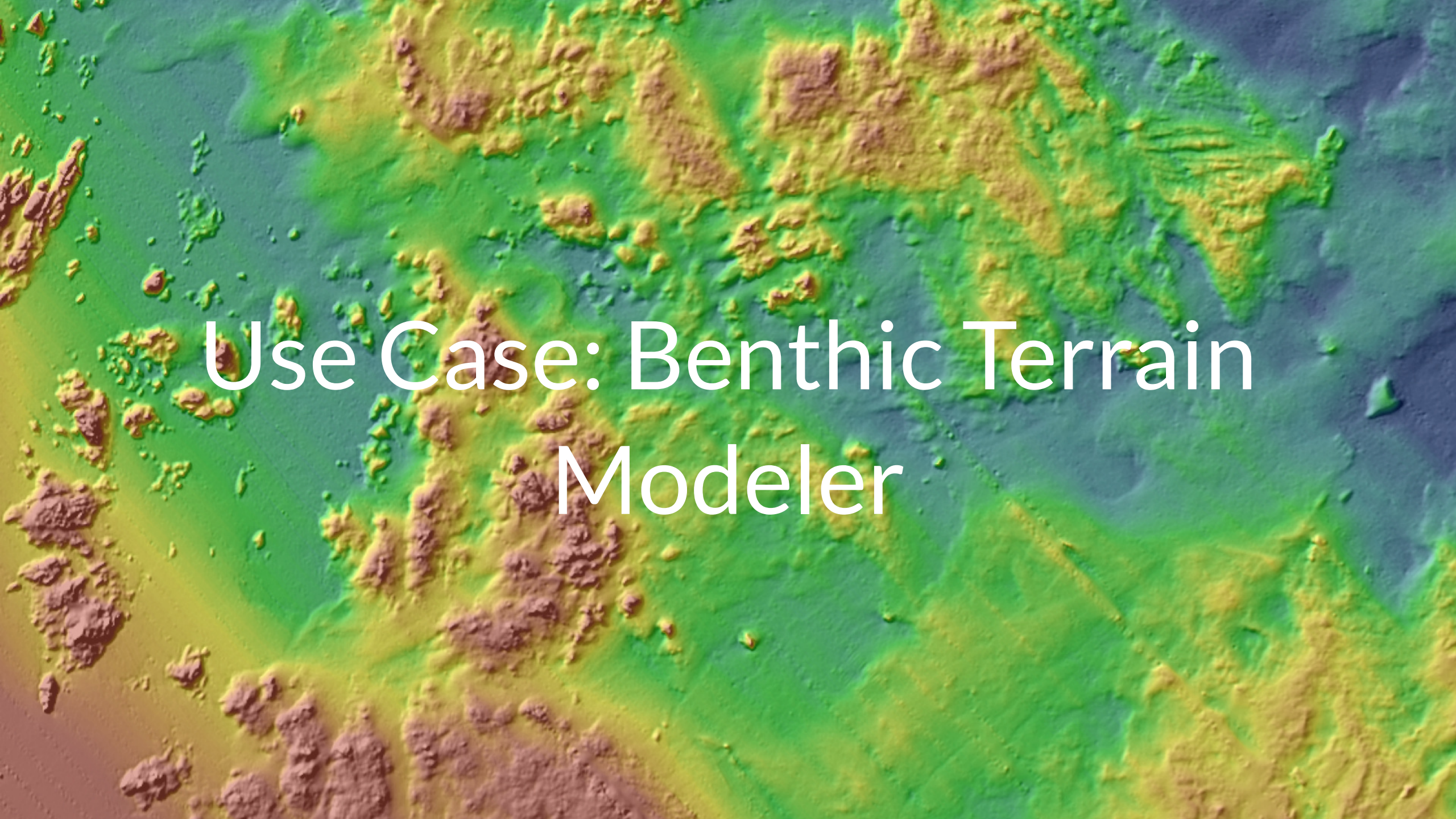
- ArcGIS and NumPy can interoperate on raster, table, and feature data.
- See Working with NumPy in ArcGIS
- In-memory data model. Example script to process by blocks if working with larger data.
- Use `arcgis`' SeDF if you need a high-level interface for feature data

ArcGIS with NumPy



Computational methods for:

- Integration (scipy.integrate)
- Optimization (scipy.optimize)
- Interpolation (scipy.interpolate)
- Fourier Transforms (scipy.fft)
- Signal Processing (scipy.signal)
- Linear Algebra (scipy.linalg)
- Spatial (scipy.spatial)


Use Case: Benthic Terrain Modeler

Lightweight SciPy Integration

- Using `scipy.ndimage` to perform basic multiscale analysis
- Using `scipy.stats` to compute circular statistics

Lightweight SciPy Integration

Example source

```
import arcpy
import scipy.ndimage as nd
from matplotlib import pyplot as plt

ras = "data/input_raster.tif"
r = arcpy.RasterToNumPyArray(ras, "", 200, 200, 0)

fig = plt.figure(figsize=(10, 10))
```

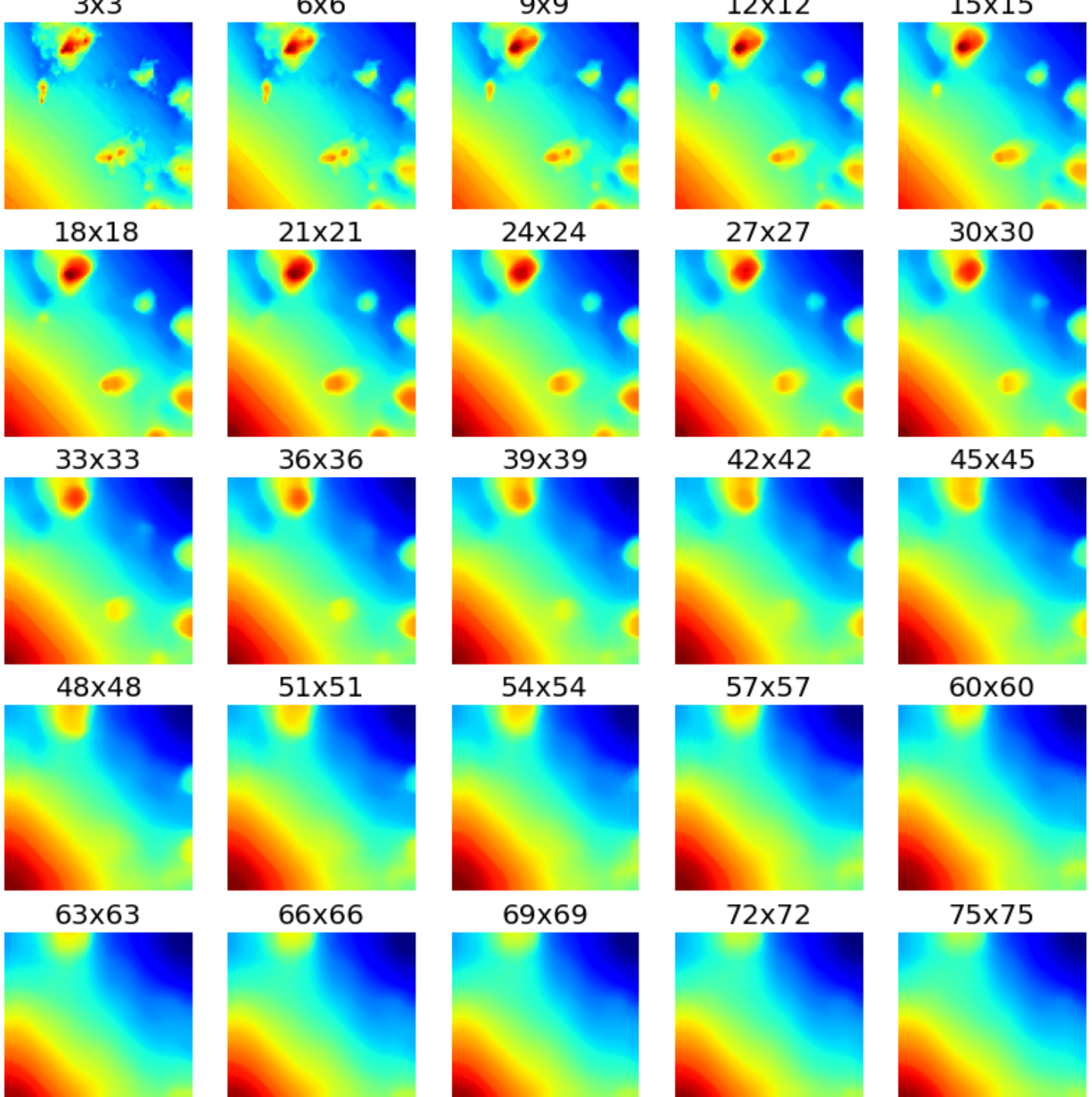
Lightweight SciPy Integration

```
for i in xrange(25):
    size = (i+1) * 3

    print "running {}".format(size)
    med = nd.median_filter(r, size)

    a = fig.add_subplot(5, 5,i+1)
    plt.imshow(med, interpolation='nearest')
    a.set_title('{}x{}'.format(size, size))
    plt.axis('off')
    plt.subplots_adjust(hspace = 0.1)
    prev = med

plt.savefig("btm-scale-compare.png", bbox_inches='tight')
```


3x3
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42x42
45x45
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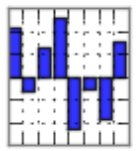
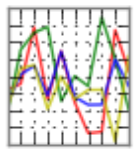
51x51
54x54
57x57
60x60
63x63
66x66
69x69
72x72
75x75

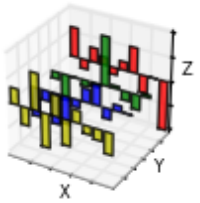
Pandas

pandas

$$y_{it} = \beta' x_{it} + \mu_i + \epsilon_{it}$$







- **Pan**el **Da**ta — like R “data frames”
- Bring a robust data *analysis* workflow to Python
- Data frames are fundamental — treat tabular (and multi-dimensional) data as a labeled, indexed series of observations.

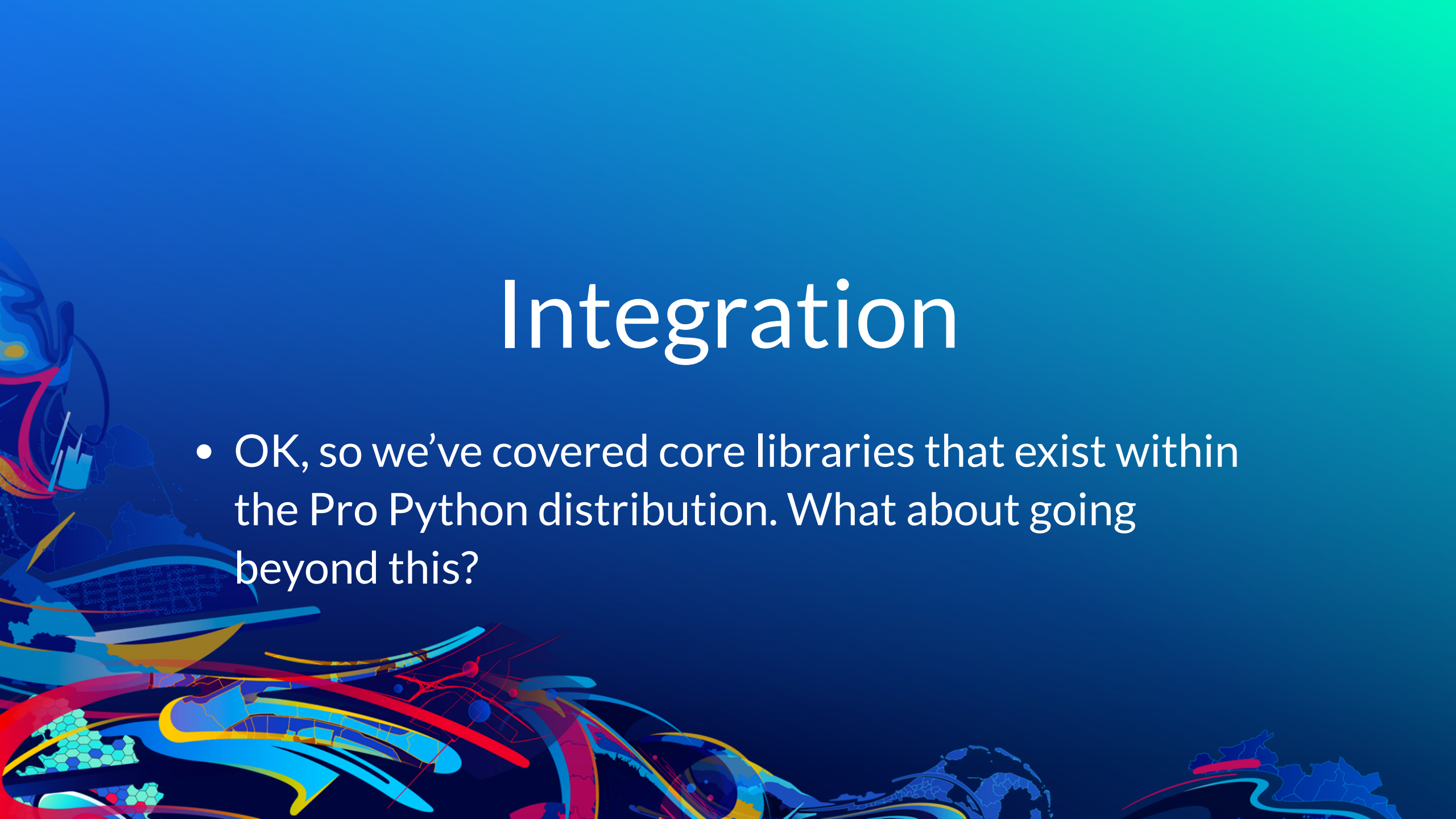
Spatial Data Frames

- Same data frame model + geometries
- ArcPy + ArcGIS API for Python
- Continues to expand and improve performance

Integration

Integration

- OK, so we've covered core libraries that exist within the Pro Python distribution. What about going beyond this?



Integration

What kind of code is being run?

Bring your own Existing libraries	Your components and ecosystem tools
Domain specific tools Tools built and supported by Esri	The frameworks + tools that bind to them

- The Principle of stack minimization

Demo: Pandas

- Python is embraced in many fields as a way to create a standard API

Demo: MetPy & Tying It Together

Integration

Leverage the broad data science ecosystems of R and Python

Drive Integrated Code

Pro Python Distribution
Environment Management
Docker Runtimes (Hosted)
https://anaconda.org/esri

ArcPy and ArcGIS API

Integration includes:
- NumPy
- Pandas
- PyTorch
- Jupyter Notebooks

R-ArcGIS Bridge

RStudio
Geoprocessing Tools
Web Tools
Jupyter Notebooks

Statistical Languages

R

- R Statistical Programming Language
- Powerful core data structures for analysis and data manipulation
- Unparalleled breath of statistical routines (17,000+ packages)
- Less fast out of the box esp for large datasets

R-ArcGIS Bridge

- Access to local and remote data
- Transform to native R spatial types (`sf`, `sp`, `raster`)
- Call ArcPy through `reticulate`
- Use in RStudio
- Make GP tools which call R

SAS

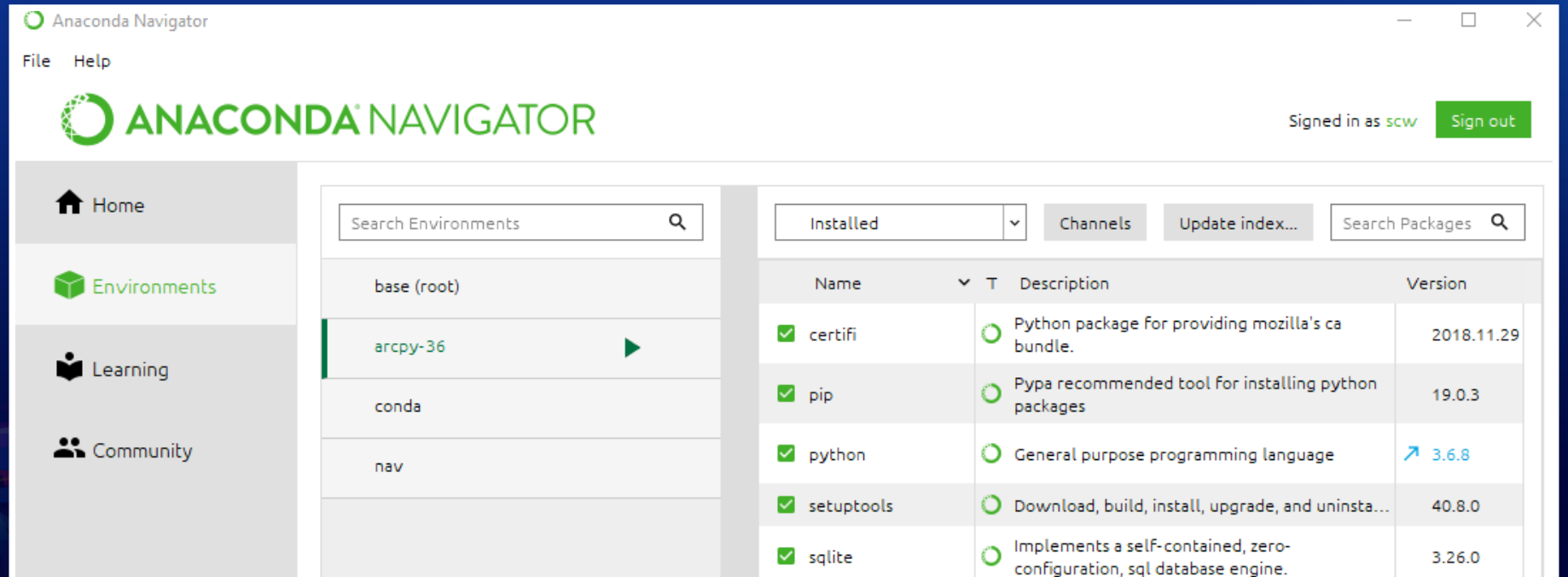
- Statistical Analysis System
- Focus on business intelligence and predictive analytics
- Very efficient for large datasets

Demo: SAS

from future import *

Deep Learning in Pro

Pro External Environments



Python: Road Ahead

- Upgrade Python environments across Pro releases
- Command line experience first for early adopters
- Upgrades to `conda`, offline packages, performance
- High performance interoperability with external datasources

Resources

New to Python

- Courses:
  - Programming for Everybody
  - Codecademy: Python Track
- Books:
  - Learn Python the Hard Way
  - How to Think Like a Computer Scientist

GIS Focused

- Python Scripting for ArcGIS
- ArcPy and ArcGIS - Geospatial Analysis with Python
- Python Developers GeoNet Community
- GIS Stackexchange

Scientific

Courses:

- Python Scientific Lecture Notes
- High Performance Scientific Computing
- Coding the Matrix: Linear Algebra through Computer Science Applications
- The Data Scientist's Toolbox

Scientific

Books:

- Free:
  - Probabilistic Programming & Bayesian Methods for Hackers
    - very compelling book on Bayesian methods in Python, uses SciPy + PyMC.
  - Kalman and Bayesian Filters in Python

Scientific

- Paid:
  - Coding the Matrix
    - How to use linear algebra and Python to solve amazing problems.
  - Python for Data Analysis: Data Wrangling with Pandas, NumPy, and IPython
    - The cannonical book on Pandas and analysis.

Packages

Only require SciPy Stack:

- Scikit-learn:
  - Lecture material
  - Includes SVMs, can use those for image processing among other things…
- FilterPy, Kalman filtering and optimal estimation:
  - FilterPy on GitHub
- An extensive list of machine learning packages

Code

- ArcPy + SciPy on Github
- raster-functions
  - An open source collection of function chains to show how to do complex things using NumPy + scipy on the fly for visualization purposes
- statistics library with a handful of descriptive statistics included in Python 3.4+.

Scientific ArcGIS Extensions

- PySAL ArcGIS Toolbox
- Movement Ecology Tools for ArcGIS (ArcMET)
- Marine Geospatial Ecology Tools (MGET)
  - Combines Python, R, and MATLAB to solve a wide variety of problems
- SDMToolbox
  - species distribution & maximum entropy models

Conferences

- PyCon
  - The largest gathering of Pythonistas in the world
- SciPy
  - A meeting of Scientific Python users from all walks
- GeoPython
  - The Python event for Python and Geo enthusiasts
- PyVideo

Closing

Thanks

- Geoprocessing Team
- ArcGIS API for Python Team
- The many amazing contributors to the projects demonstrated here.
  - Get involved! All are on GitHub and happily accept contributions.