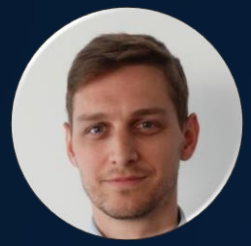
MATLAB EXPO 2021

Using MATLAB with Python

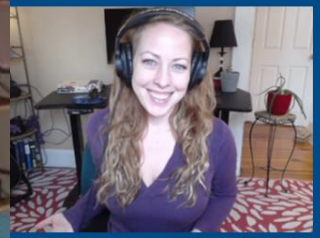
Heather Gorr, PhD & Yann Debray



MathWorks®

Top Questions Using MATLAB with Python

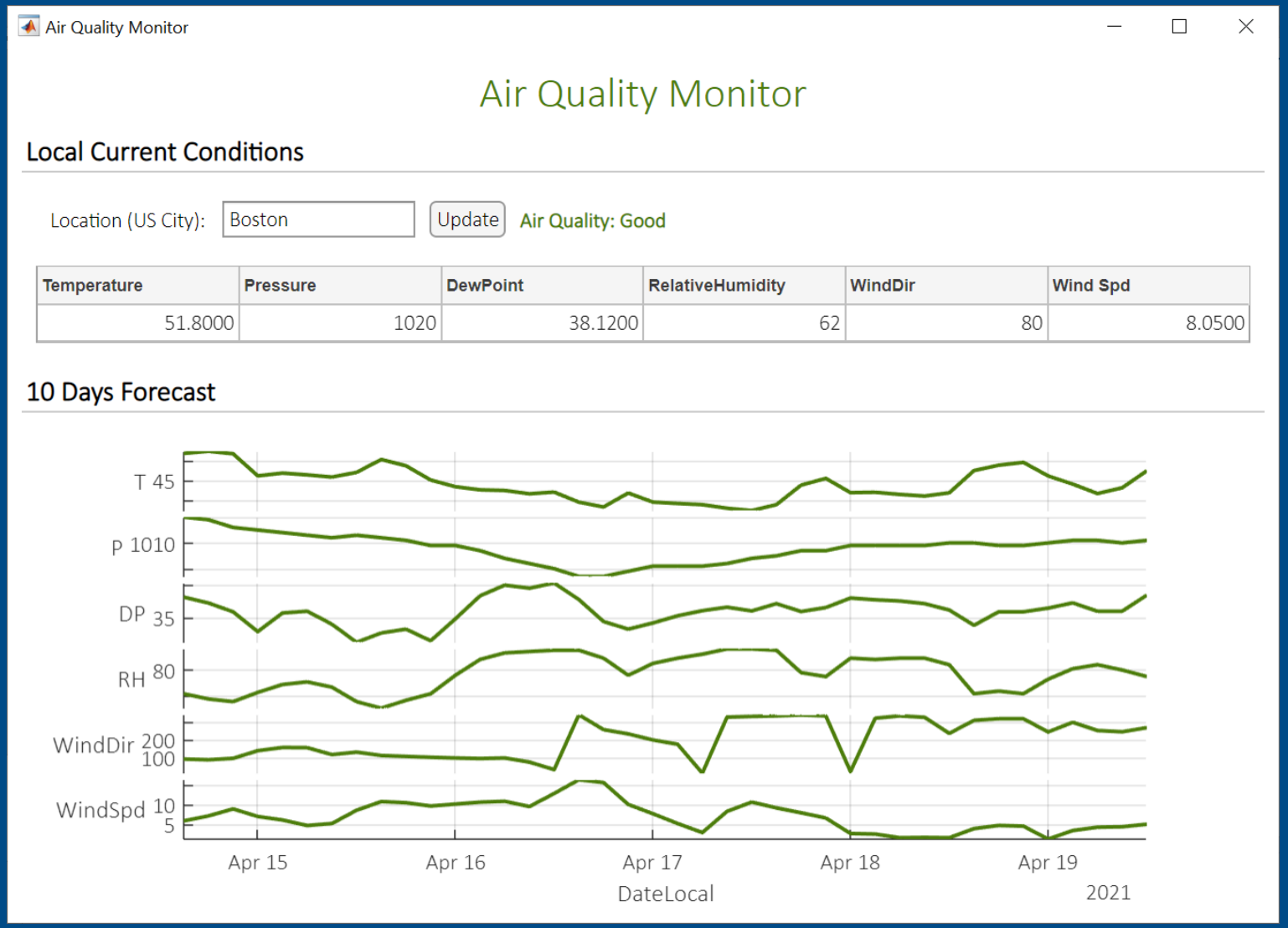
Heather Gorr, PhD



MATLAB + Python

Yann Debray

Example: Build Air Quality App using MATLAB and Python



hgorr / matlab-with-python

Notifications | Star 31 | Fork 19

Follow along with the code ☺

master | 1 branch | 0 tags

Go to file | Code

uv Moved more files :)

1_CallPythonFromMATLAB	Reorganized, added MATLAB Proj	
2_CallMATLABFromPython	Moved more files :)	
3_CallMATLABCompiledLibraryFromP...	Reorganized, updated filenames, i	
4_CallMATLABProductionServerFrom...	Moved more files :)	
5_MATLABWebApp	Reorganized, updated filenames, i	
resources/project	Reorganized, added MATLAB Project, helper files	11 days ago
.gitattributes	Reorganized, added MATLAB Project, helper files	11 days ago
.gitignore	Reorganized, added MATLAB Project, helper files	11 days ago

Clone

HTTPS GitHub CLI

https://github.com/hgorr/matlab-with-pytho

Use Git or checkout with SVN using the web URL.

Open with GitHub Desktop

Download ZIP

About

Examples using MATLAB and Python together

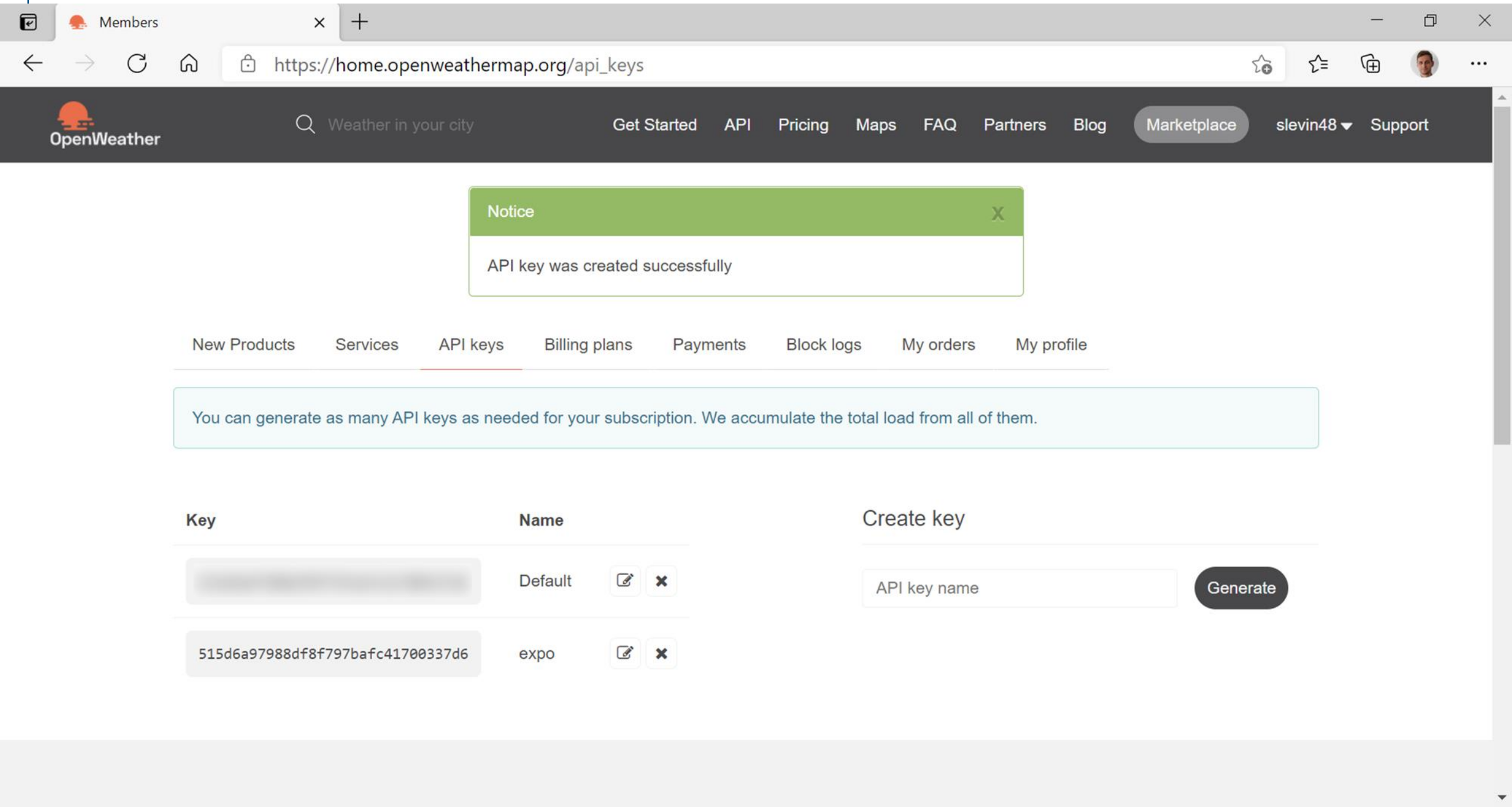
Readme

Releases

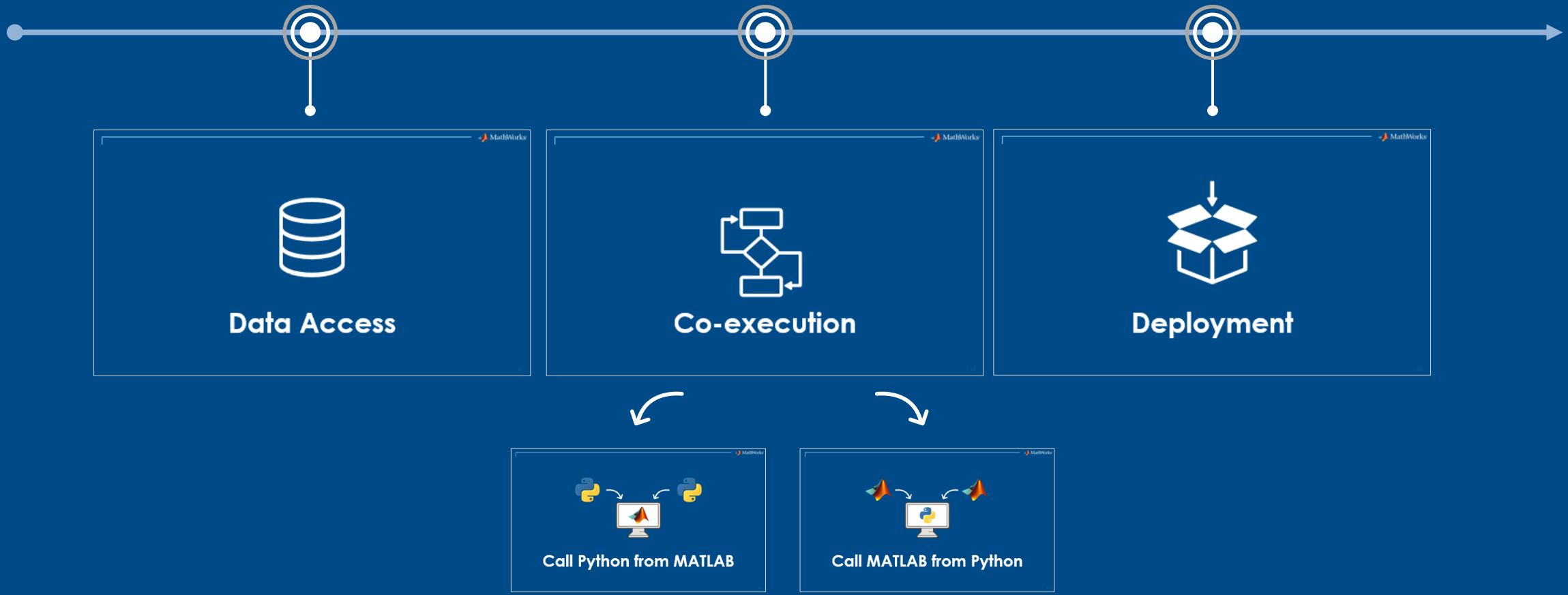
No releases published

Packages

No packages published


Members
https://home.openweathermap.org/api_keys
OpenWeather
Weather in your city
Get Started
API
Pricing
Maps
FAQ
Partners
Blog
Marketplace
slevin48
Support
Notice
API key was created successfully
New Products
Services
API keys
Billing plans
Payments
Block logs
My orders
My profile
You can generate as many API keys as needed for your subscription. We accumulate the total load from all of them.
Key
Name
Default
515d6a97988df8f797bafc41700337d6
expo
Create key
API key name
Generate

Strategies


Data Access
Co-execution
Deployment
Call Python from MATLAB
Call MATLAB from Python

Data Access

Access Data from a Web Service

https://openweathermap.org/

Data Access

Co-Execution

- Call Python from MATLAB
- Call MATLAB from Python

Deployment

OpenWeather global services

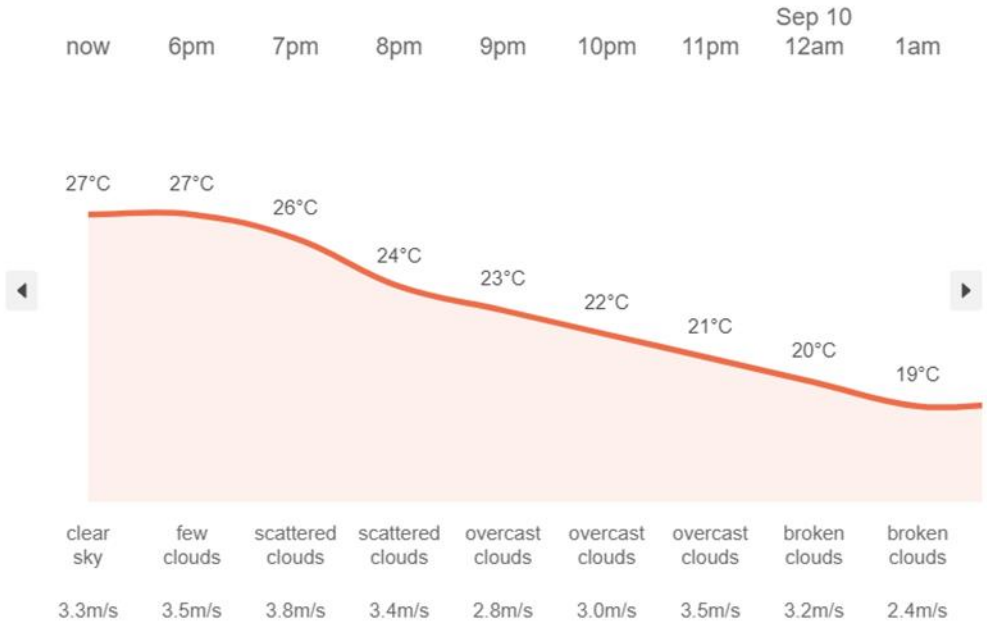
Weather forecasts, nowcasts and history in fast and elegant way

2 Billion Forecasts Per Day
2,500 new subscribers a day

2,600,000 customers
20+ weather APIs

Hourly forecast

Temperature | Precipitation



8-day forecast

Wed, Sep 09	27 / 19°C	clear sky
Thu, Sep 10	25 / 18°C	broken clouds
Fri, Sep 11	28 / 17°C	scattered clouds
Sat, Sep 12	25 / 16°C	clear sky
Sun, Sep 13	26 / 15°C	broken clouds
Mon, Sep 14	32 / 17°C	scattered clouds
Tue, Sep 15	27 / 20°C	moderate rain
Wed, Sep 16	21 / 17°C	light rain

Data Access

Co-Execution

- Call Python from MATLAB
- Call MATLAB from Python

Deployment

What type of data?

Numerical, Textual, Geolocalized, Timeseries, …

Called by:
geographical coordinates, zip codes, city name, city ID, number of cities (only in current and forecasted APIs)

https://openweathermap.org/

Store & transfer tabular data between languages

Use Apache Parquet files for memory efficient data access

- Working with Parquet files in MATLAB
- MATLAB library for Apache Arrow on GitHub

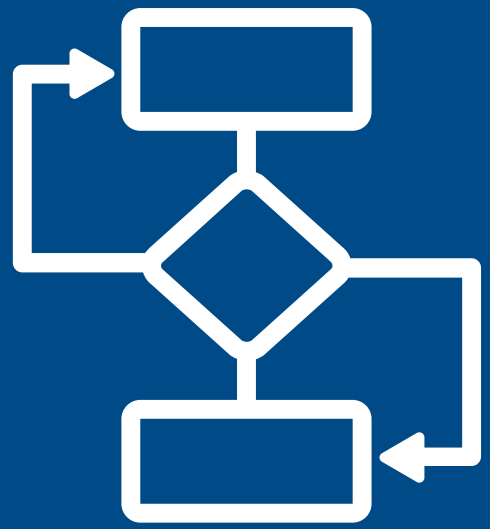

```
parquetwrite("temperatureFitting.parquet",T)
```

T = 40×3 table

	Time	Temperatures	SineFit
1	2020-07-16...	19.0200	23.8001
2	2020-07-16...	20.3300	24.6581
3	2020-07-16...	20.1300	23.0750
4	2020-07-16...	18.9300	19.9678
5	2020-07-17...	17.1500	17.1366
6	2020-07-17...	16.0200	16.2214
7	2020-07-17...	16.7900	17.7525

```
# Use parquet file as alternative to exchange tables with MATLAB
df = pd.read_parquet("temperatureFitting.parquet")
df.head()
```

	Time	Temperatures	SineFit
0	2020-07-16 12:00:00	19.02	23.800150
1	2020-07-16 15:00:00	20.33	24.658138
2	2020-07-16 18:00:00	20.13	23.074984
3	2020-07-16 21:00:00	18.93	19.967804
4	2020-07-17 00:00:00	17.15	17.136577



Co-execution

Given: Existing Python Code accessing & preparing weather data

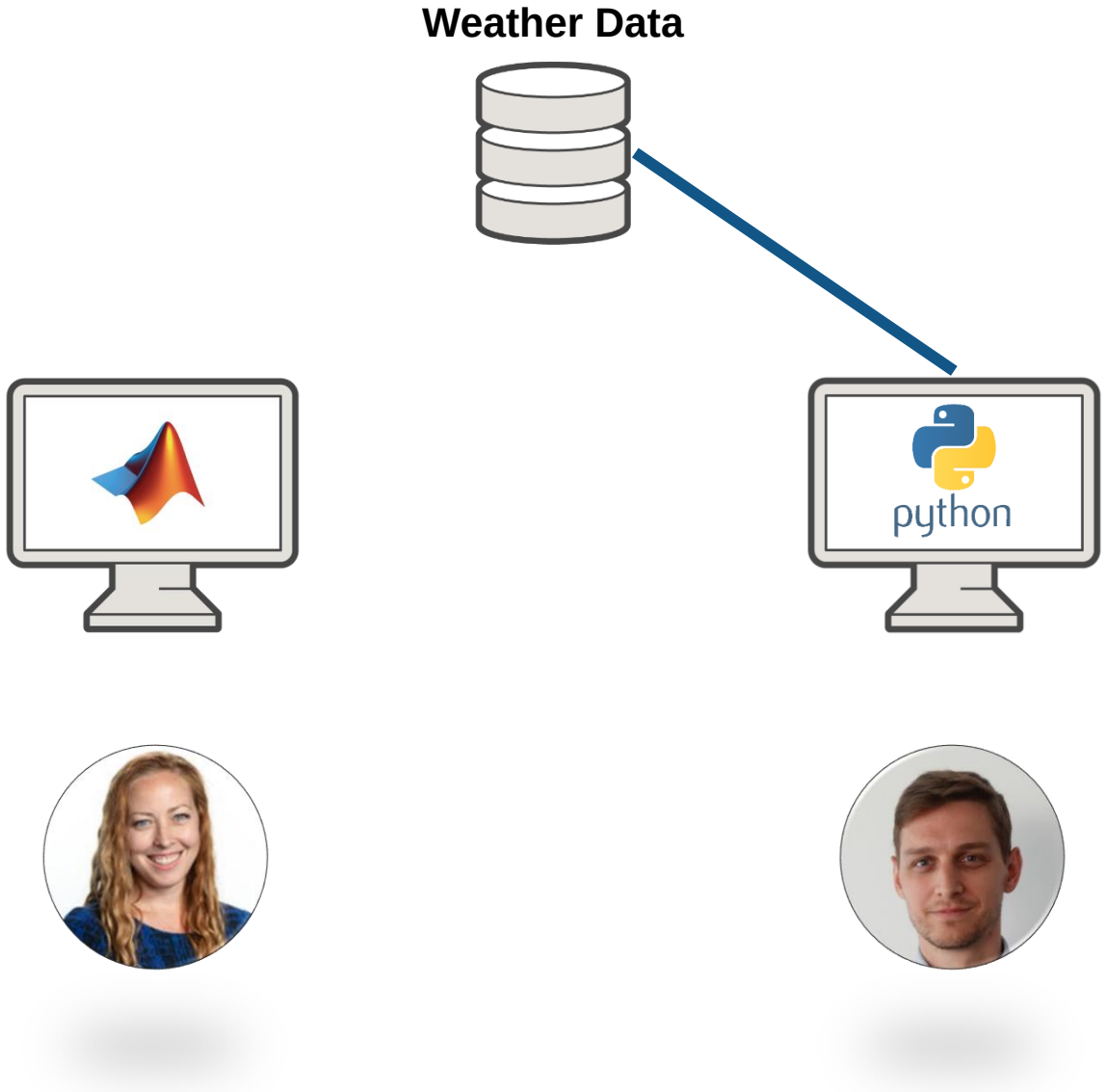
Data preparation | Modeling | Deployment

Data Access

Co-Execution

- Call Python from MATLAB
- Call MATLAB from Python

Deployment



Call Python from MATLAB

Data preparation | Modeling | Deployment

Data Access

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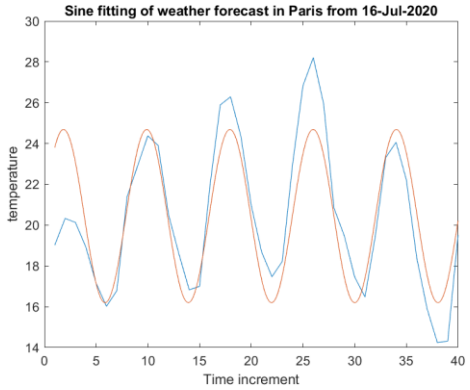

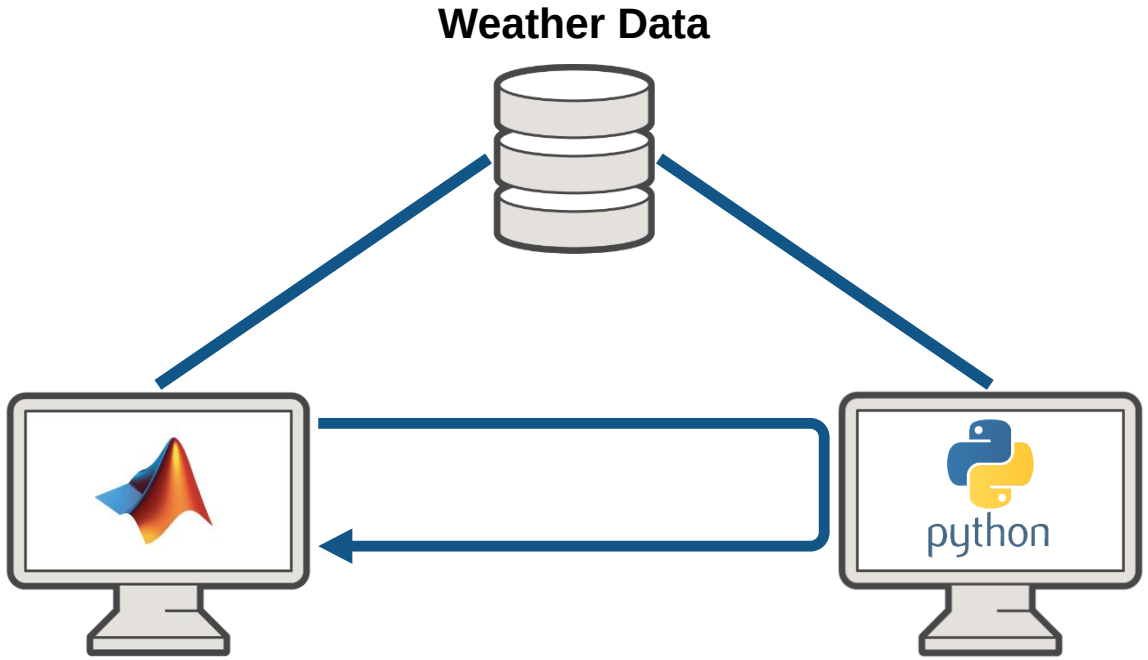

Call MATLAB from Python

Data preparation | Modeling | Deployment

Data Access

Co-Execution

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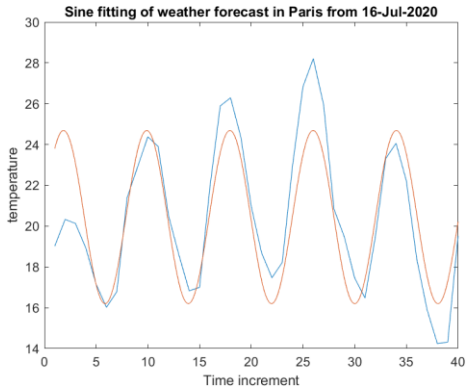

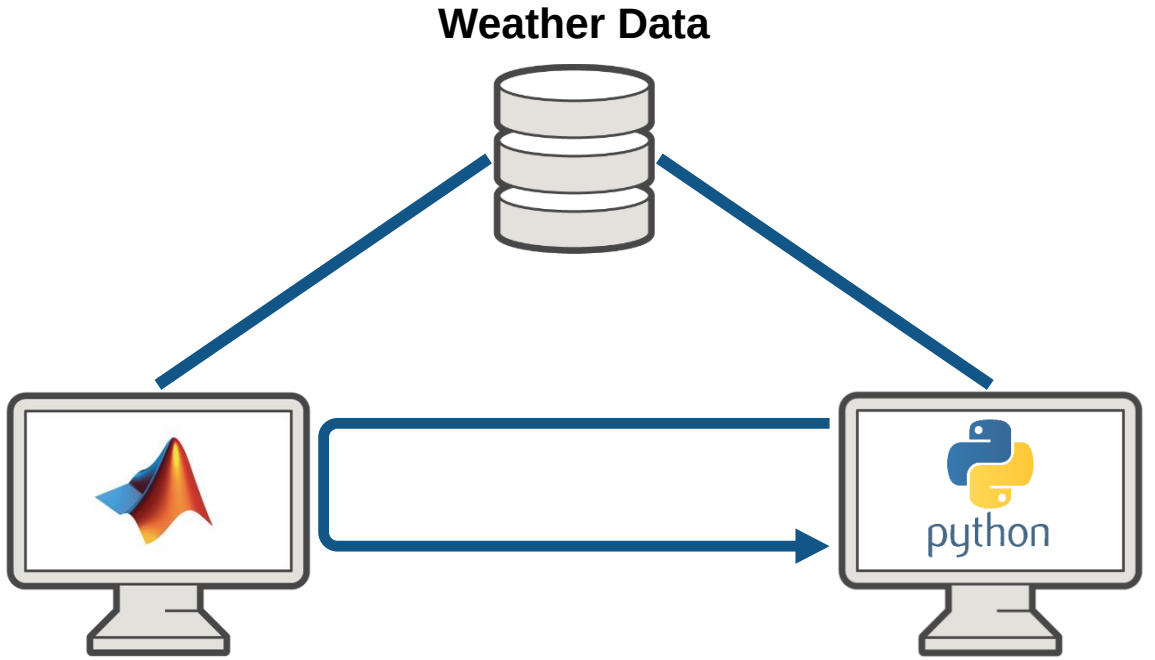

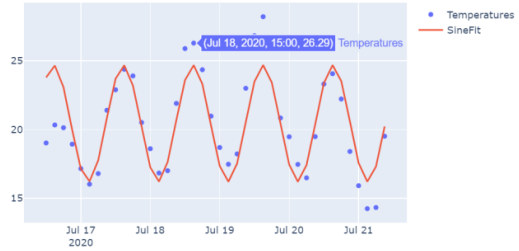

Deploy:
MATLAB Analytics into Python

Data preparation → Modeling → Deployment

Data Access

Co-Execution

- Call Python from MATLAB
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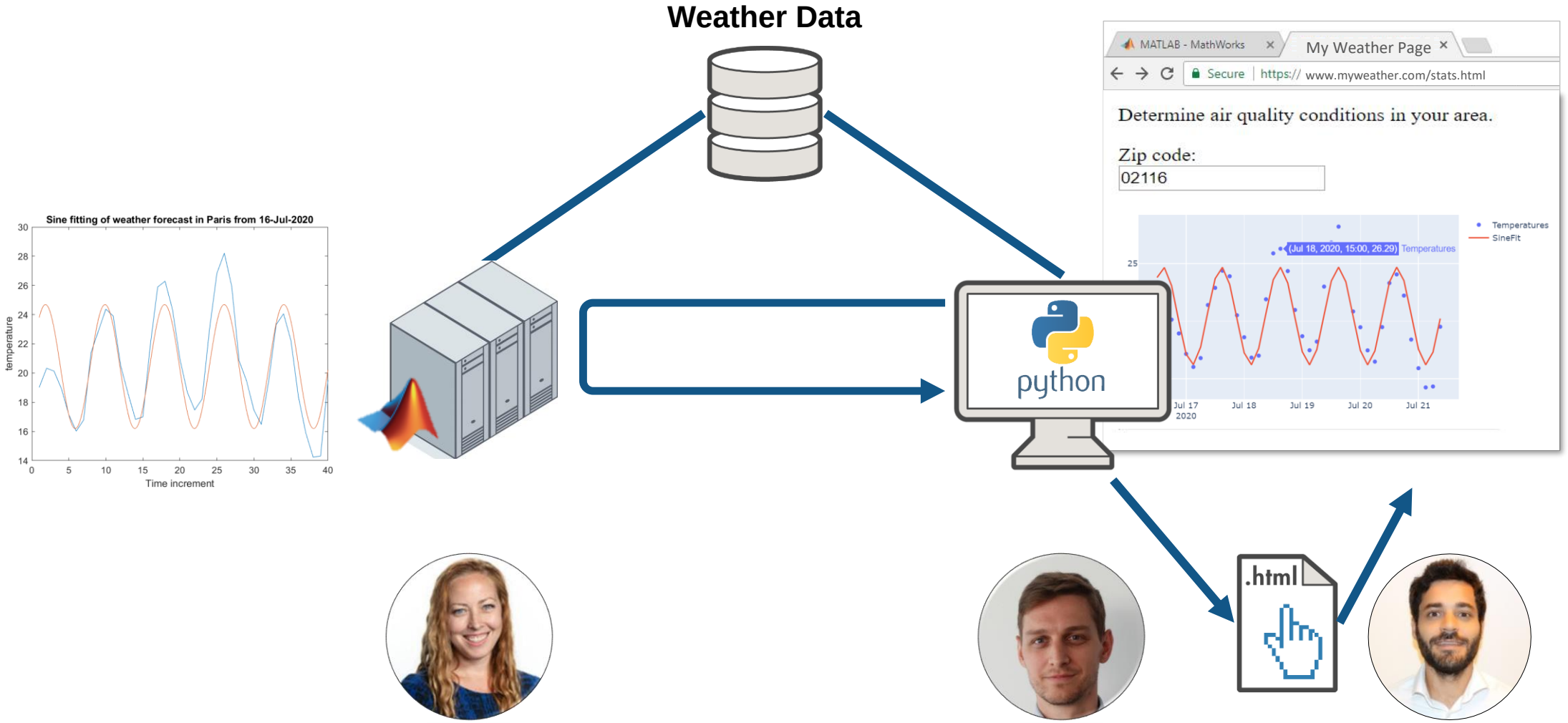
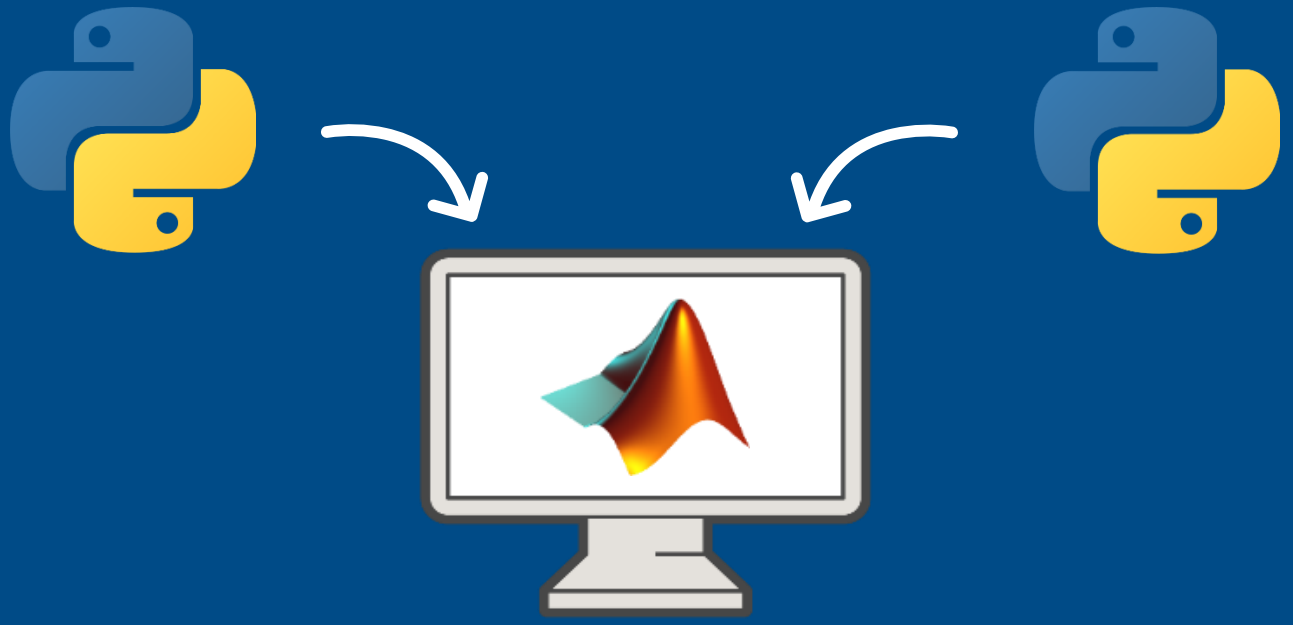
Deployment



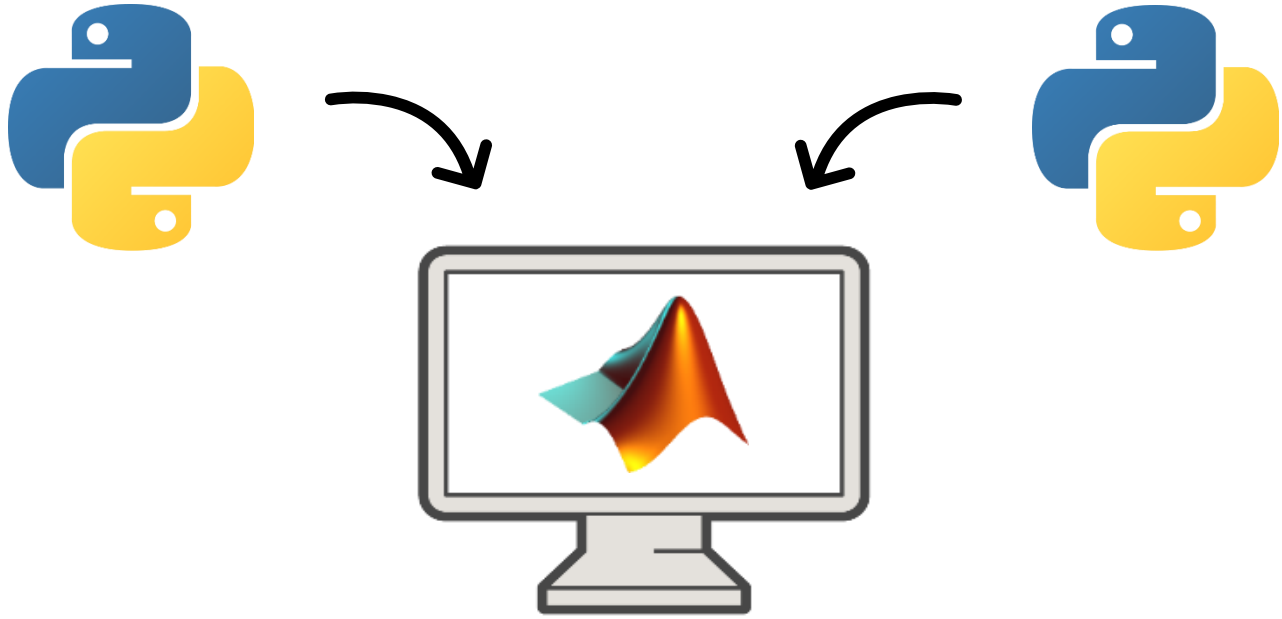


Call Python from MATLAB

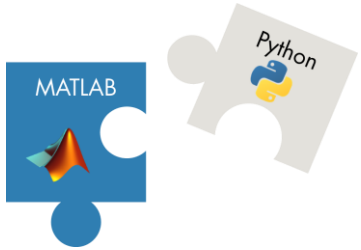
Why Call Python from MATLAB?

Already working in MATLAB, and:

- Want to reuse existing Python code
- Need functionality available in Python
- Want to collaborate with Python users



Calling Python libraries from MATLAB



Data Access

Co-Execution

- Call Python from MATLAB
- Call MATLAB from Python

Deployment

Use the weather.py module to get the air quality for Paris. This is a user-defined Python module which includes functions to read and parse the current and forecasted weather data by location.

```
jsonData = py.weather.get_current_weather("Paris","France",apikey.Key)
```

```
jsonData =
  Python dict with no properties.

    {'coord': {'lon': 2.35, 'lat': 48.85}, 'weather': [{'id': 803, 'main': 'Cloud
```

```
def get_current_weather(city, country, apikey):
    # get current conditions in specified location
    # get_current_weather('boston','us',key)
    import urllib.request
    import json
    # read current conditions
    try:
        url = "https://api.openweathermap.org/data/2.5/weather?q="+city+","+country+"&appid="+apikey
        response = urllib.request.urlopen(url)
        html = response.read()
        json_data = json.loads(html)

    except urllib.error.URLError:
        # if weather API doesnt work, read the file
        json_data = read_backup(city)

    return json_data
```

Parse the json data returned from the weather API.

The Python dictionary can be represented as a MATLAB struct.

```
weatherData = py.weather.parse_json(jsondata);
struct(weatherData)
```

```
ans = struct with fields:
           temp: 18.7100
     feels_like: 17.3000
       temp_min: 17.7800
       temp_max: [1×1 py.int]
```

Use a function (`prepData.m`) to prepare data for machine learning (create a table with the expected variable names, preprocessing steps, etc).

```
currentData = prepData(weatherData)
```

currentData = 1×12 table

	DateLocal	city	StateName	T	P	DP	RH	WindDir	WindSpd
1	01-Jul-2020 11:...	"Paris"	Ile de France	21.6200	20.2600	349.2200	1010	5.1000	73

First steps to connect to Python

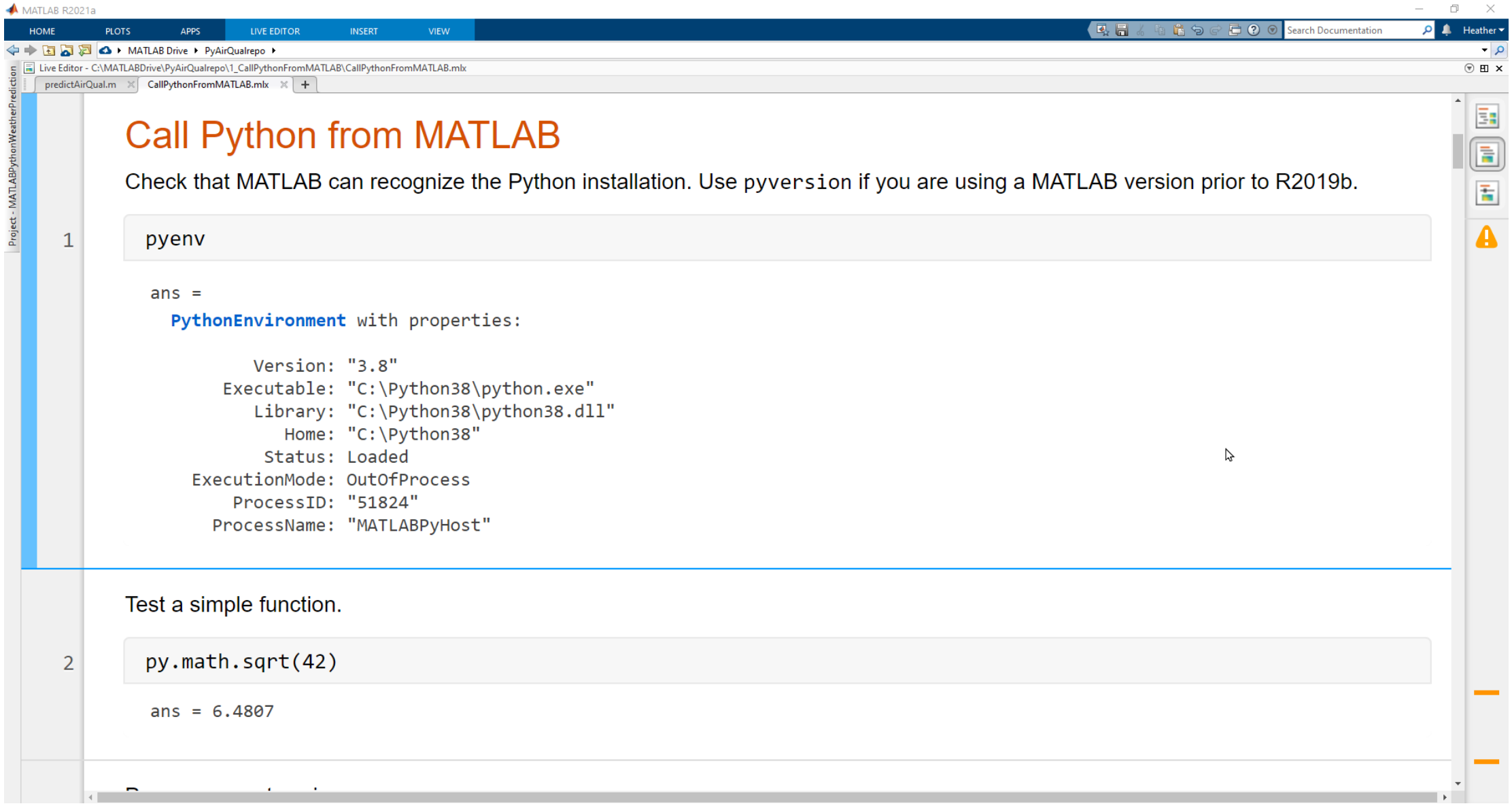
callPythonFromMATLAB.mlx

Data Access

Co-Execution

- Call Python from MATLAB
- Call MATLAB from Python

Deployment



Call the weather service with Python and import data into MATLAB

Data Access

Co-Execution

- Call Python from MATLAB
- Call MATLAB from Python

Deployment

MATLAB R2020b

HOME | PLOTS | APPS | LIVE EDITOR | INSERT | VIEW

Search Documentation | Yann

MATLAB Drive ▸ weather ▸ matlab-and-python ▸

Live Editor - C:\Users\ydebray\MATLAB Drive\weather\CallPythonFromMATLAB.mlx *

CallPythonFromMATLAB.mlx *

Handle timeseries with the weather forecast

Now let's get back to France, and look at the weather forecast for this weekend in Paris!

```
13 jsonData = py.weather.get_forecast("Paris",apikey.Key);
14 forecastData = py.weather.parse_forecast(jsonData);
15 forecast = struct(forecastData)
```

```
forecast = struct with fields:
    current_time: [1x40 py.list]
            temp: [1x1 py.array.array]
             deg: [1x1 py.array.array]
           speed: [1x1 py.array.array]
        humidity: [1x1 py.array.array]
        pressure: [1x1 py.array.array]
```

```
16 forecast.temp
```

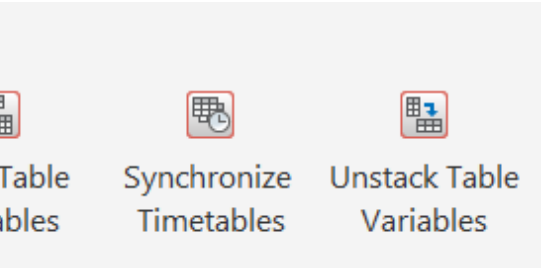
```
ans =
  Python array:

    9.3800   12.3700   13.6100   11.3200    9.6100    8.5200    7.8200    7.3400    9.9600   12.0100   12.7500   11.8800   11.4100   11.0600   10.8300   10.3500   11.8000

    Use details function to view the properties of the Python object.

    Use single function to convert to a MATLAB array.
```

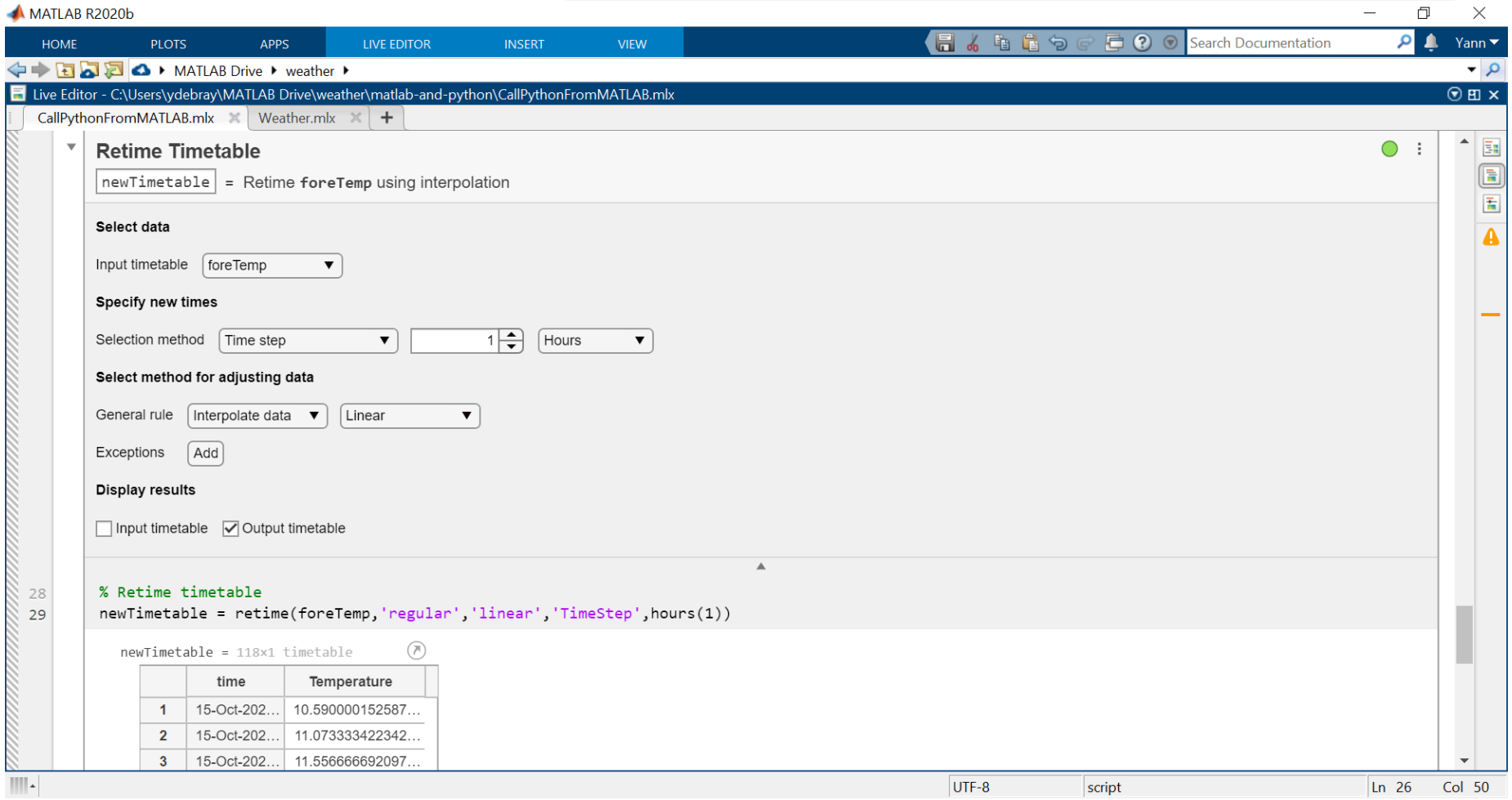
```
17 tempForecast = double(forecast.temp)
```

```
tempForecast = 1x40
     9.3800   12.3700   13.6100   11.3200    9.6100    8.5200    7.8200    7.3400    9.9600   12.0100   12.7500   11.8800   11.4100   11.0600   10.8300   10.3500 ...
```

UTF-8 | script

Live Tasks





Data Access

Co-Execution

- Call Python from MATLAB
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Deployment

Live Tasks

DATA PREPROCESSING

Clean Missing Data | Clean Outlier Data | Find Change Points | Find Local Extrema | Remove Trends | Smooth Data

Remove Trends

`detrendedData` = Remove linear trend from **`tempForecast`**

Select data

Input data: tempForecast ▼ X-axis: default ▼

Specify trend parameters

Degree: Linear ▼

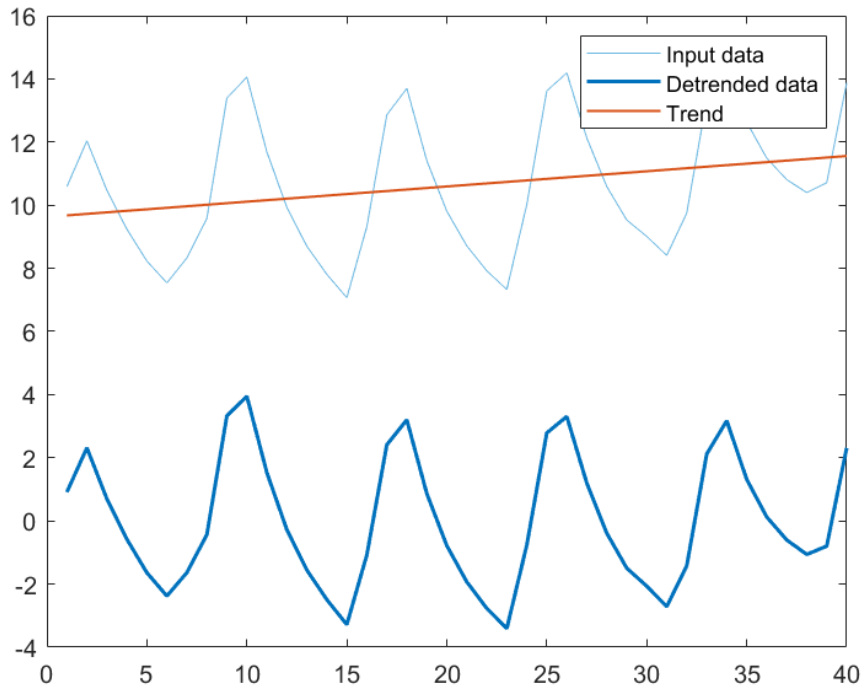
Breakpoints: None ▼

Display results

☑ Detrended data ☑ Input data ☑ Trend

```
% Remove trend from data
detrendedData = detrend(tempForecast);

% Display results
clf
plot(tempForecast,'Color',[109 185 226]
hold on
plot(detrendedData,'Color',[0 114 189]/
    'DisplayName','Detrended data')
plot(tempForecast-detrendedData,'Color'
    'DisplayName','Trend')
```



Data Access

Co-Execution

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Deployment

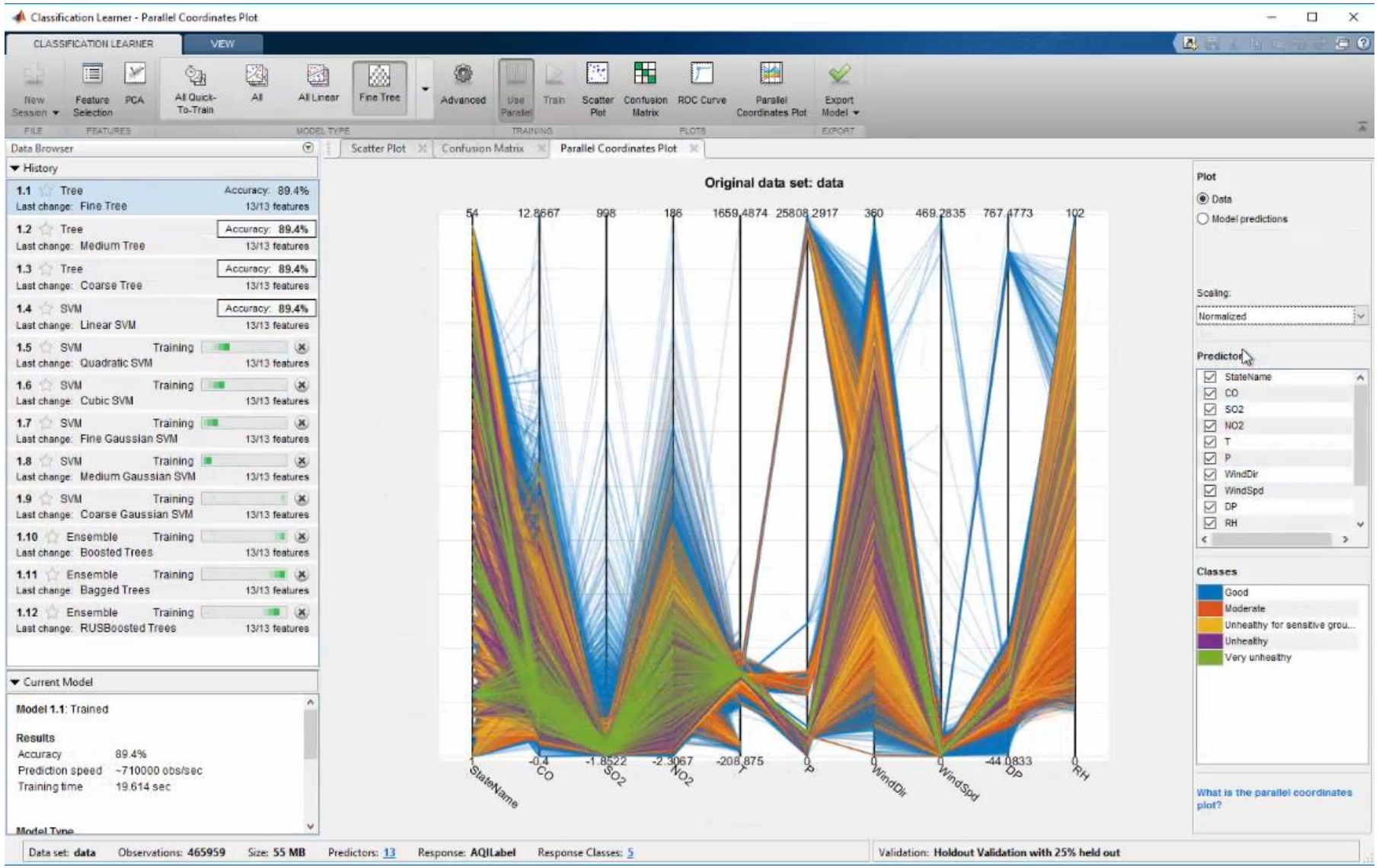
Train air quality prediction model in MATLAB

Data Access

Co-Execution

- Call Python from MATLAB
- Call MATLAB from Python

Deployment



Use air quality prediction model on Python data

Data Access

Co-Execution

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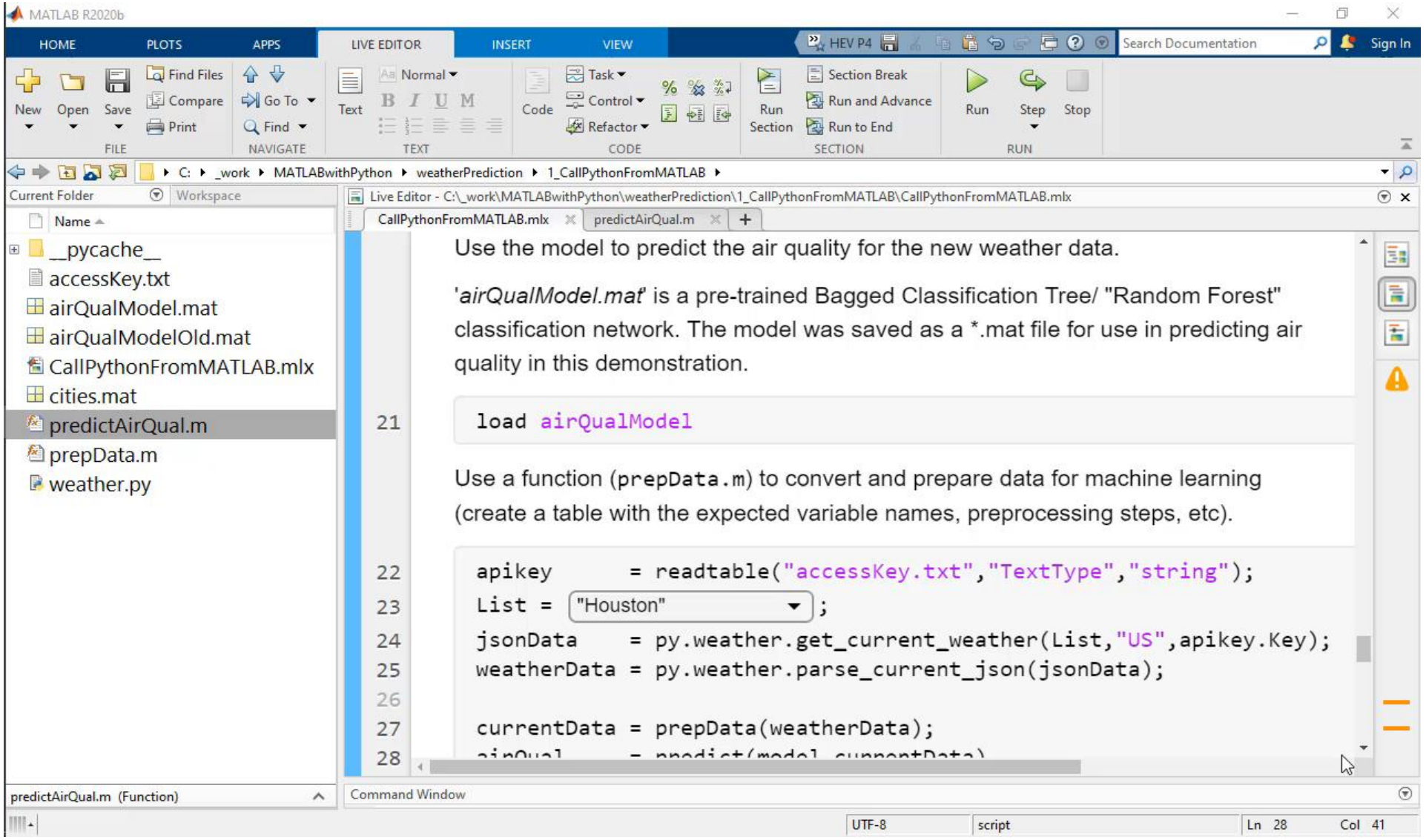
- Call MATLAB from Python

Deployment



Recap: Calling Python from MATLAB

Data are automatically converted where possible

Otherwise convert explicitly

MATLAB to Python Data Type Mapping

R2021a

When calling a Python® function, MATLAB® converts MATLAB data into types that best represent the data to the Python language.

Pass Scalar Values to Python

MATLAB Input Argument Type — Scalar Values Only	Resulting Python `py.` Type	Examples
`double` `single`	`float`	Use Python Numeric Variables in MATLAB

Complex `single`
Complex `double`
	`complex`	`z = complex(1,2);`
		`py.cmath.polar(z)`
		
		`ans =`
		`Python tuple with no properties.`
		
		`(2.23606797749979, 1.1071487177940904)`

`int8`
`uint8`
`int16`
`uint16`
`int32`
	`int`	

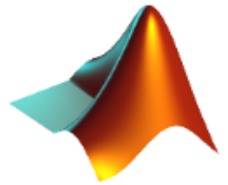
`uint32`
`int64`
`uint64`
	`int`
	`long` (version 2.7 only)	

`NaN`	`float("nan")`	
`Inf`	`float("inf")`	
`string` scalar	`str`	Use Python str Variables in MATLAB

https://mathworks.com/help/matlab/matlab_external/passing-data-to-python.html

Note the syntax differences when calling Python from MATLAB

Python



MATLAB

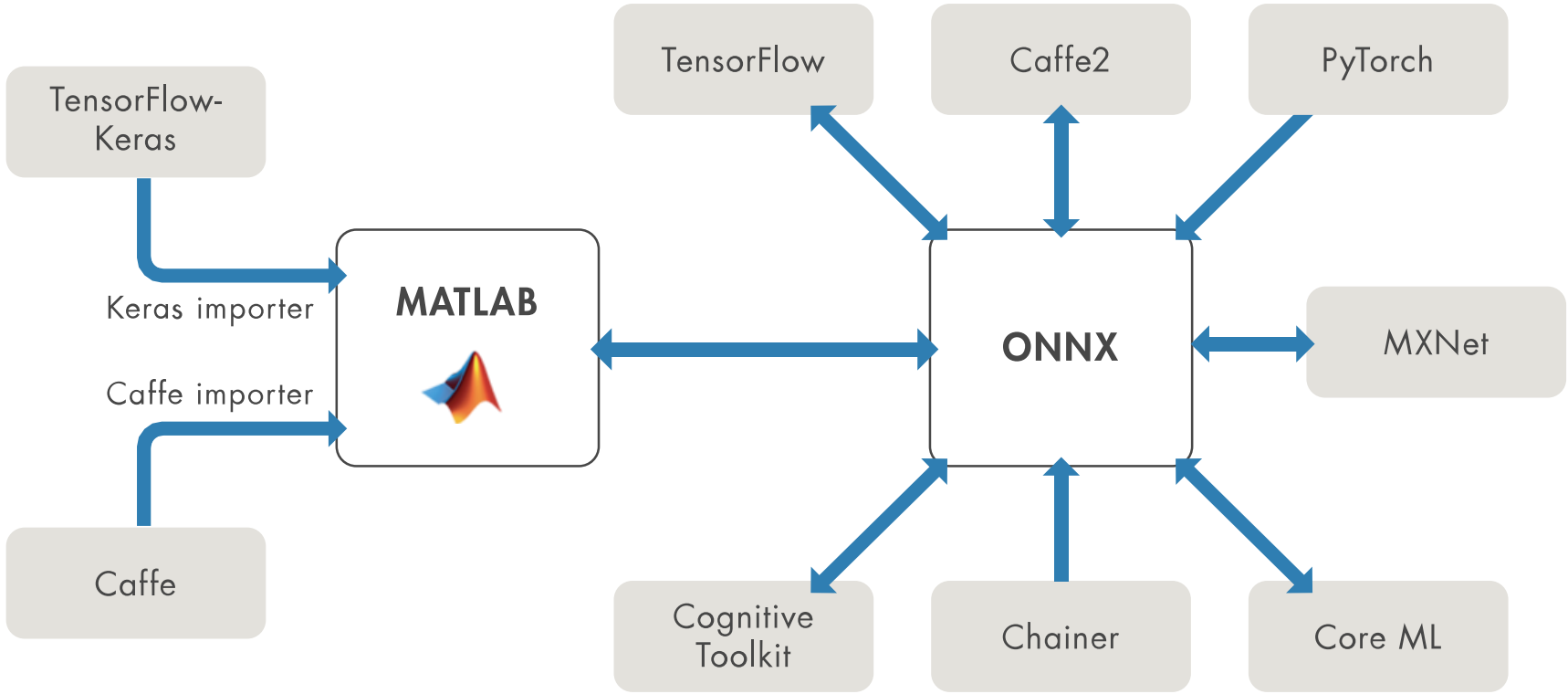
```
>>> import math
>>> math.sqrt(42)
```

```
>> py.math.sqrt(42)
```

```
>>> print('hello','world',sep=', ')
```

```
>> py.print('hello','world',...
       pyargs('sep',', '))
```

Model Interoperability



https://www.mathworks.com/solutions/deep-learning/models.html

Data Access

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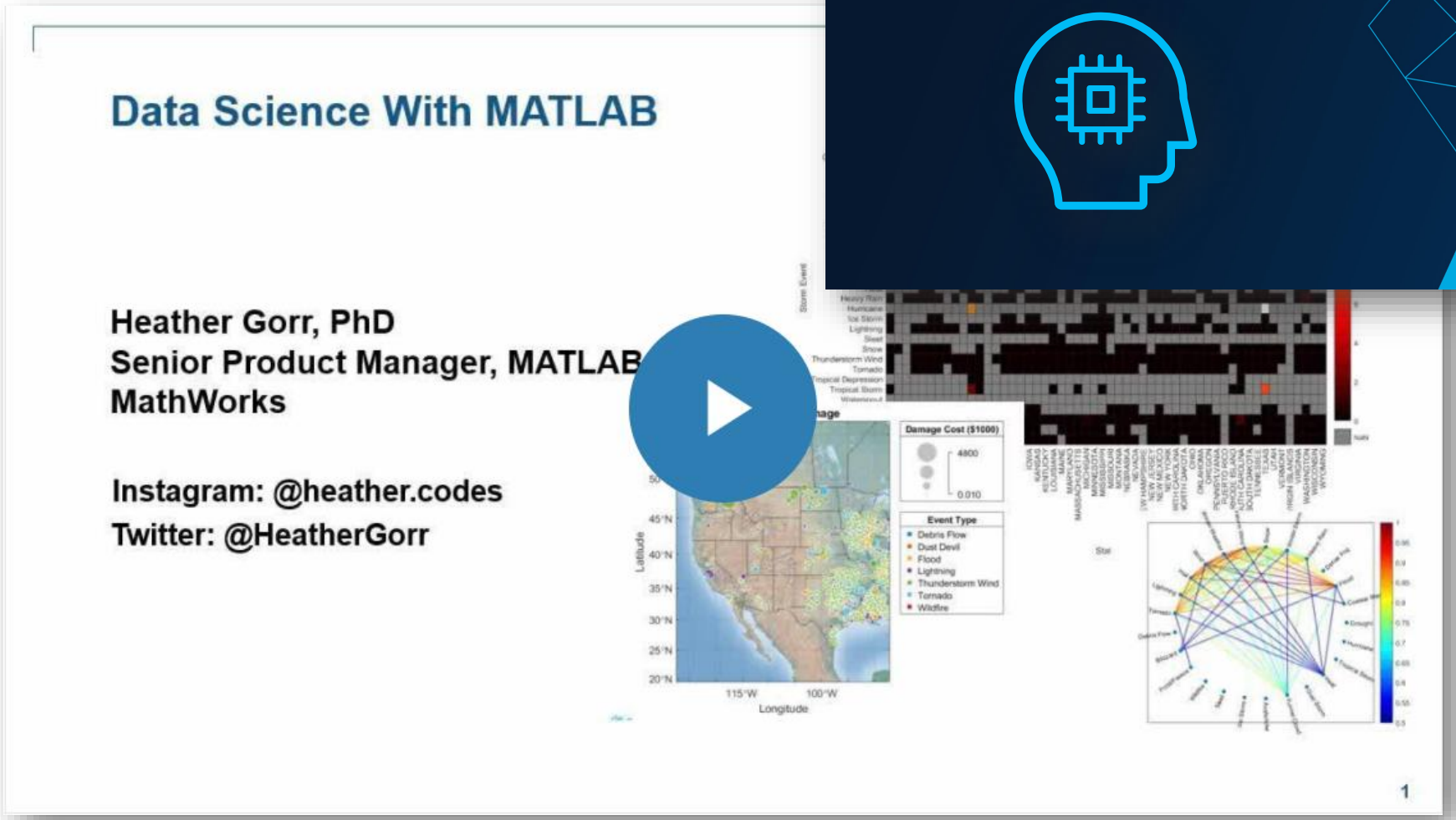
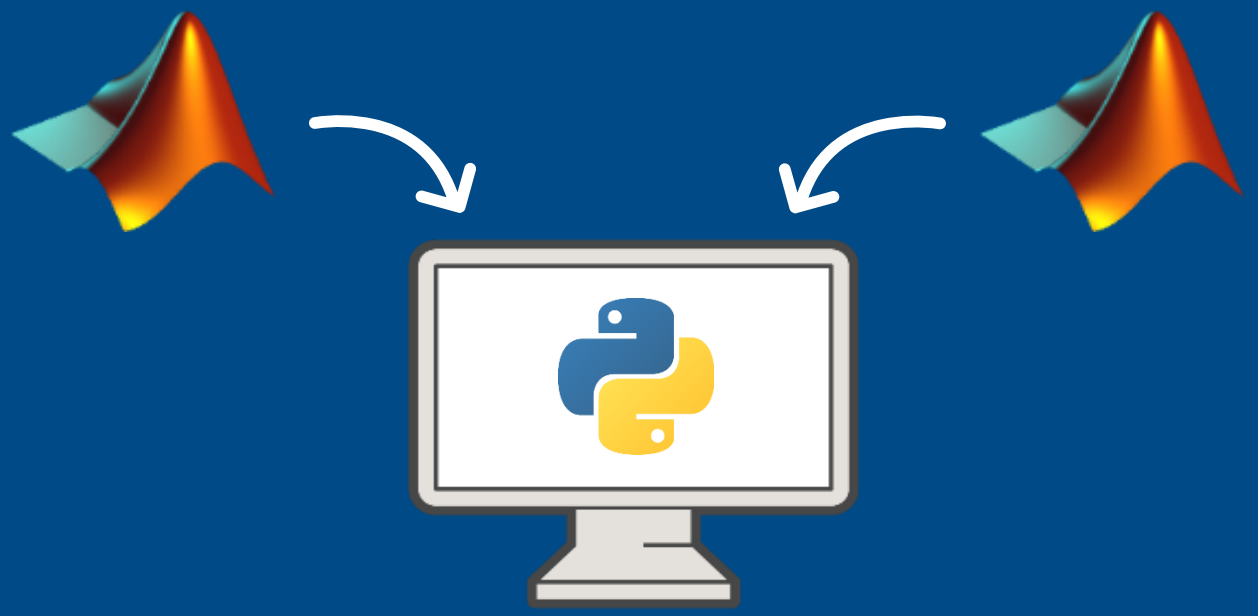
Learn more about

Data Science with MATLAB





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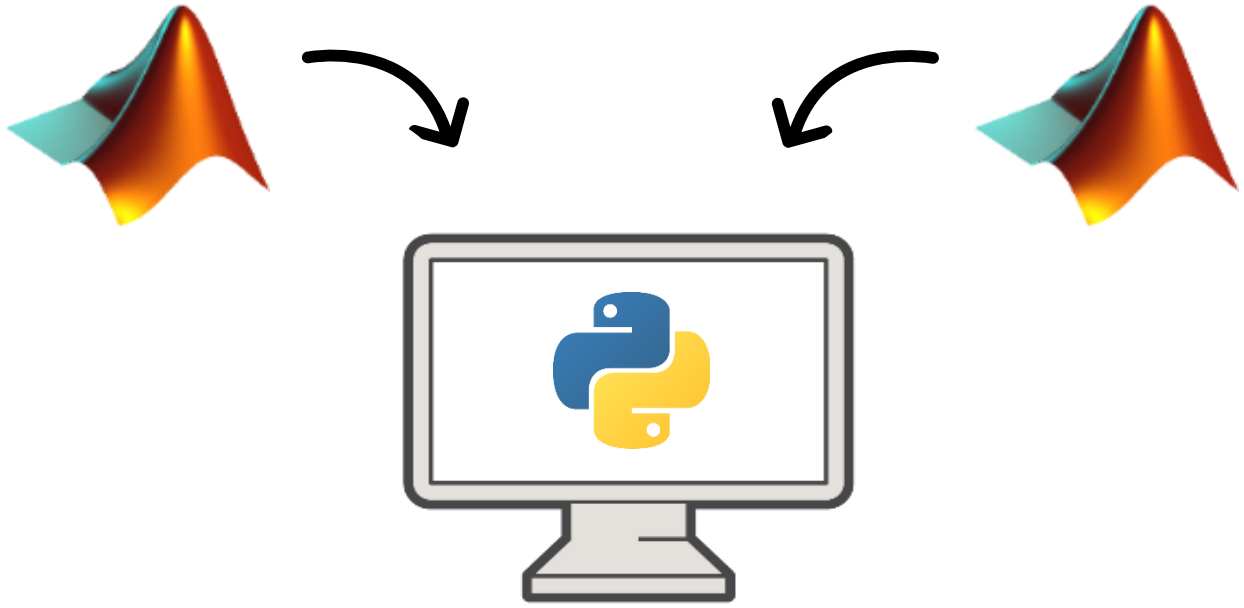
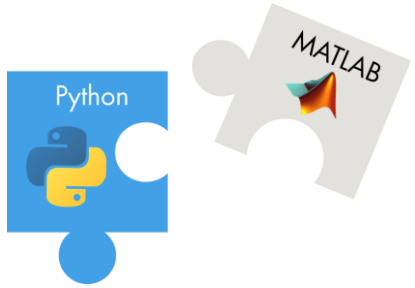


Call MATLAB from Python

To perform advanced analytics



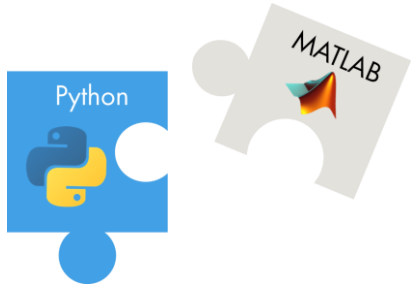
- Calling MATLAB from Python
  - via MATLAB Engine API

```
Administrator: Windows PowerShell
Windows PowerShell
Copyright (C) Microsoft Corporation. All rights reserved.

Try the new cross-platform PowerShell https://aka.ms/pscore6

PS C:\WINDOWS\system32> cd 'C:\Program Files\MATLAB\R2021a\extern\engines\python'
PS C:\Program Files\MATLAB\R2021a\extern\engines\python> python setup.py install
```

```
>>> import matlab.engine
>>> eng = matlab.engine.start_matlab()
>>>
```

Call MATLAB from Python

To perform advanced analytics

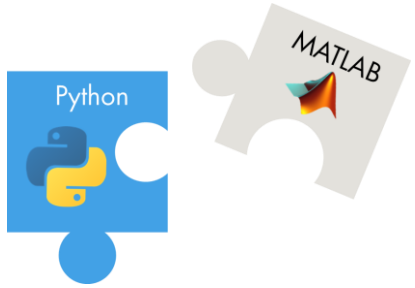


- Calling MATLAB from Python
  - via MATLAB Engine API

```
>>> import matlab.engine
>>> eng = matlab.engine.start_matlab()
>>> eng.sqrt(42.0)
6.48074069840786
>>>


>>> z = eng.gcd(42.0,8.0,nargout=1)
>>> print(z)
2.0
>>> z = eng.gcd(42.0,8.0,nargout=3)
>>> print(z)
(2.0, 1.0, -5.0)
```

Call MATLAB from Python

To perform advanced analytics



- Calling MATLAB from Python
  - via MATLAB Engine API

[1]
```
import matlab.engine
eng = matlab.engine.start_matlab()
```

Test a simple function

[2]
```
x = eng.sqrt(float(43))
print(x)
```
```
6.557438524302
```

Call MATLAB function which returns multiple outputs.

[3]
```
y = eng.gcd(42.0,8.0,nargout=1)
print(y)
```
```
2.0
```

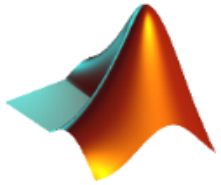
[4]
```
#this returns the Bézout coefficients to solve the Diophantine equation ... not a mistake!
z = eng.gcd(42.0, 8.0, nargout=3)
print(z)
```
```
(2.0, 1.0, -5.0)
```

More in Deployment:

- via MATLAB Runtime (MATLAB Compiler SDK)
- via MATLAB Production Server

Recap: Calling MATLAB from Python

Note the syntax differences when calling MATLAB from Python



MATLAB

Python

```
>> [s,sidx] = sort(x)
```

→

```
>>> s = eng.sort(x,nargout=2)
```

```
>> foo(x)
```

```
>>> eng.foo(x,nargout=0)
```

```
>> C = A + B
```

→

```
>>> C = eng.plus(A,B)
```

Data are automatically converted where possible

Data Access

Co-Execution

- Call Python from MATLAB
- **Call MATLAB from Python**

Deployment

Pass Data to MATLAB from Python

R2021a

Python Type to MATLAB Scalar Type Mapping

When you pass Python® data as input arguments to MATLAB® functions, the MATLAB Engine for Python converts the data into equivalent MATLAB data types.

Python Input Argument Type — Scalar Values Only	Resulting MATLAB Data Type
`float`	`double`
`complex`	Complex `double`
`int`	`int64`
`long` (Python 2.7 only)	`int64`
`float(nan)`	`NaN`
`float(inf)`	`Inf`
`bool`	`logical`
`str`	`char`
`unicode` (Python 2.7 only)	`char`
`dict`	Structure if all keys are strings not supported otherwise

Python Container to MATLAB Array Type Mapping

Python Input Argument Type — Container	Resulting MATLAB Data Type
`matlab` numeric array object (see MATLAB Arrays as Python Variables)	Numeric array
`bytearray`	`uint8` array
`bytes` (Python 3.x) `bytes` (Python 2.7)	`uint8` array `char` array
`list`	Cell array
`set`	Cell array
`tuple`	Cell array

https://mathworks.com/help/matlab/matlab_external/pass-data-to-matlab-from-python.html

Deployment

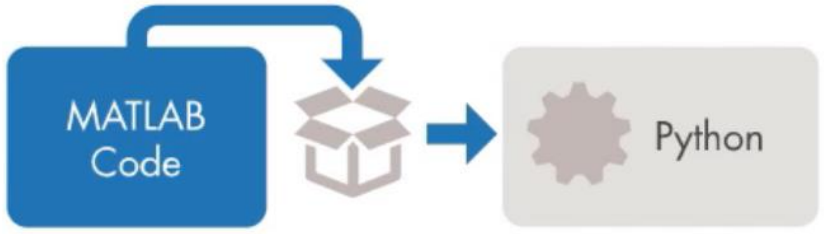
Generate Python library from MATLAB functions

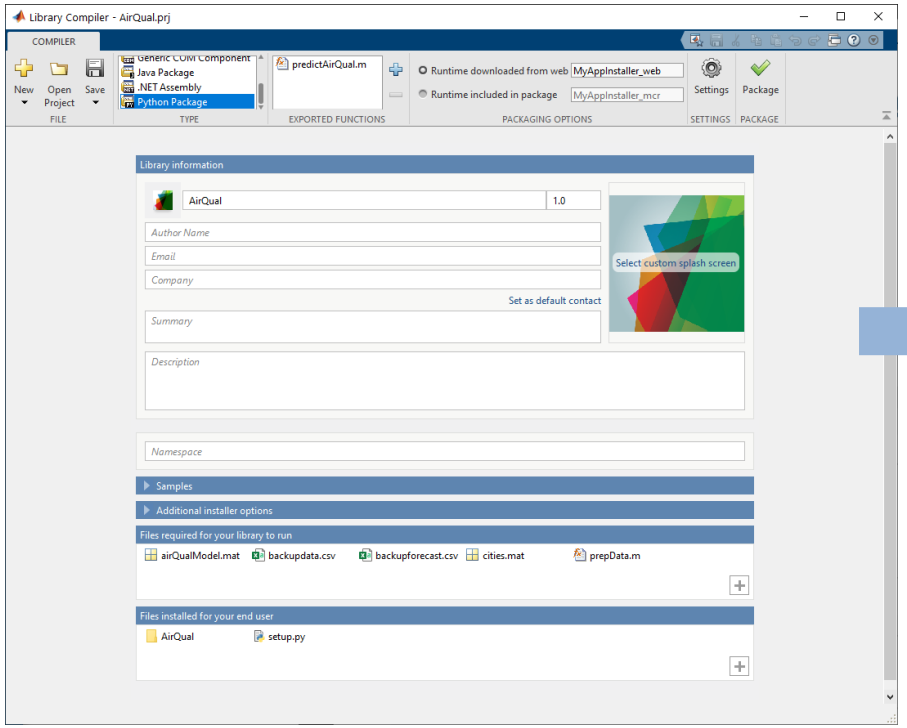
Data Access

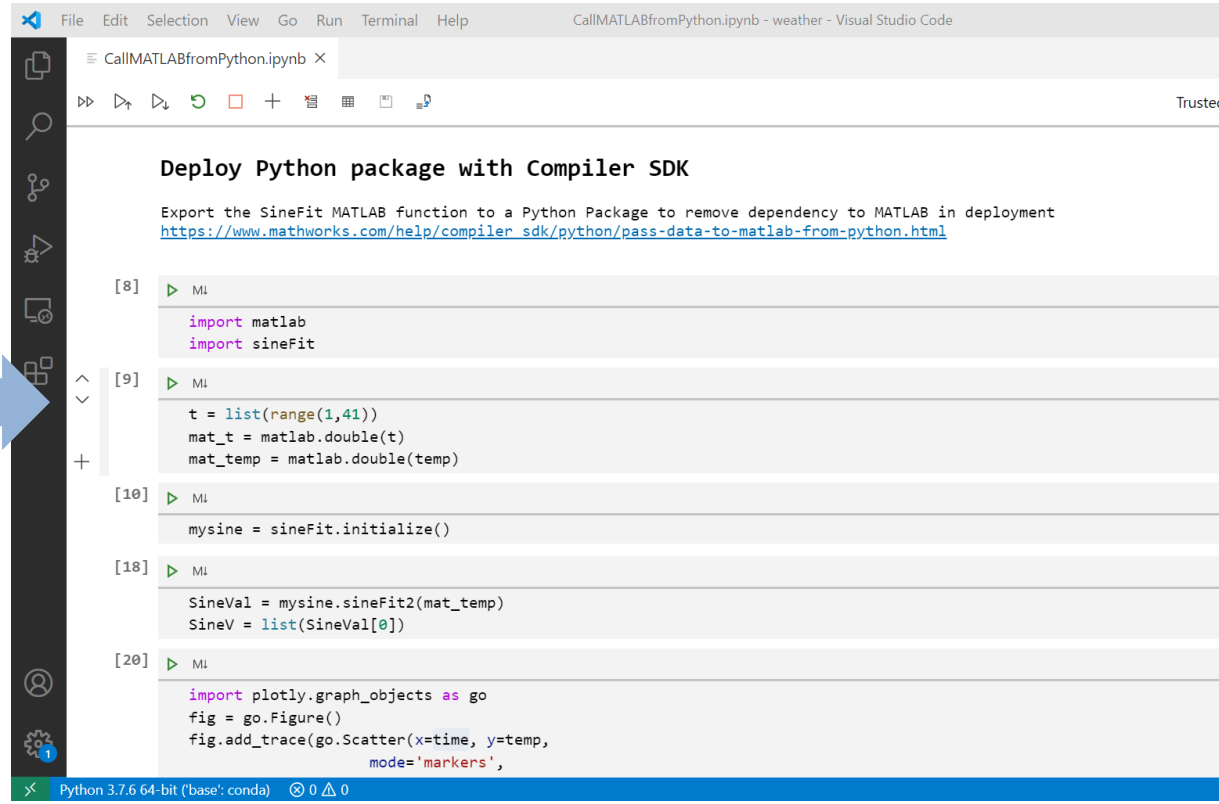
Co-Execution

- Call Python from MATLAB
- Call MATLAB from Python

Deployment







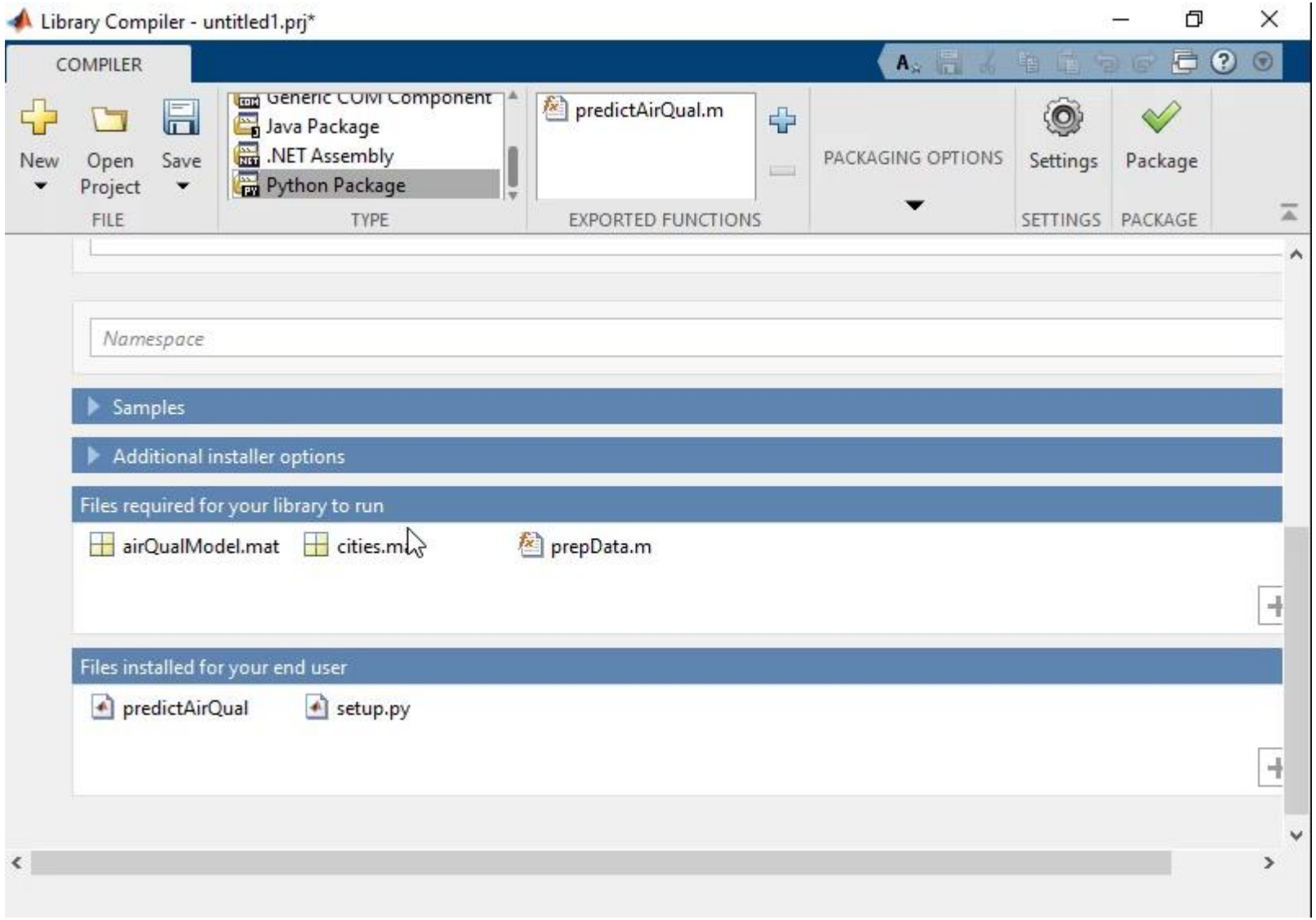
Data Access

Co-Execution

- Call Python from MATLAB
- Call MATLAB from Python

Deployment

Generate Python library from MATLAB functions



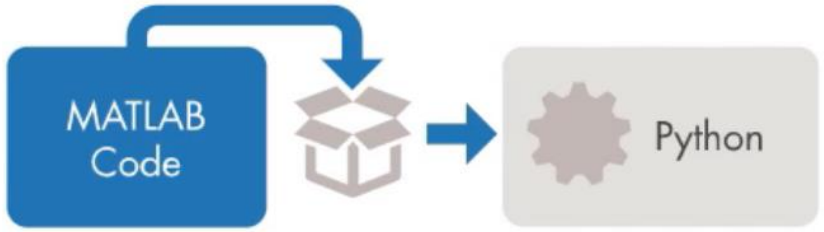
Data Access

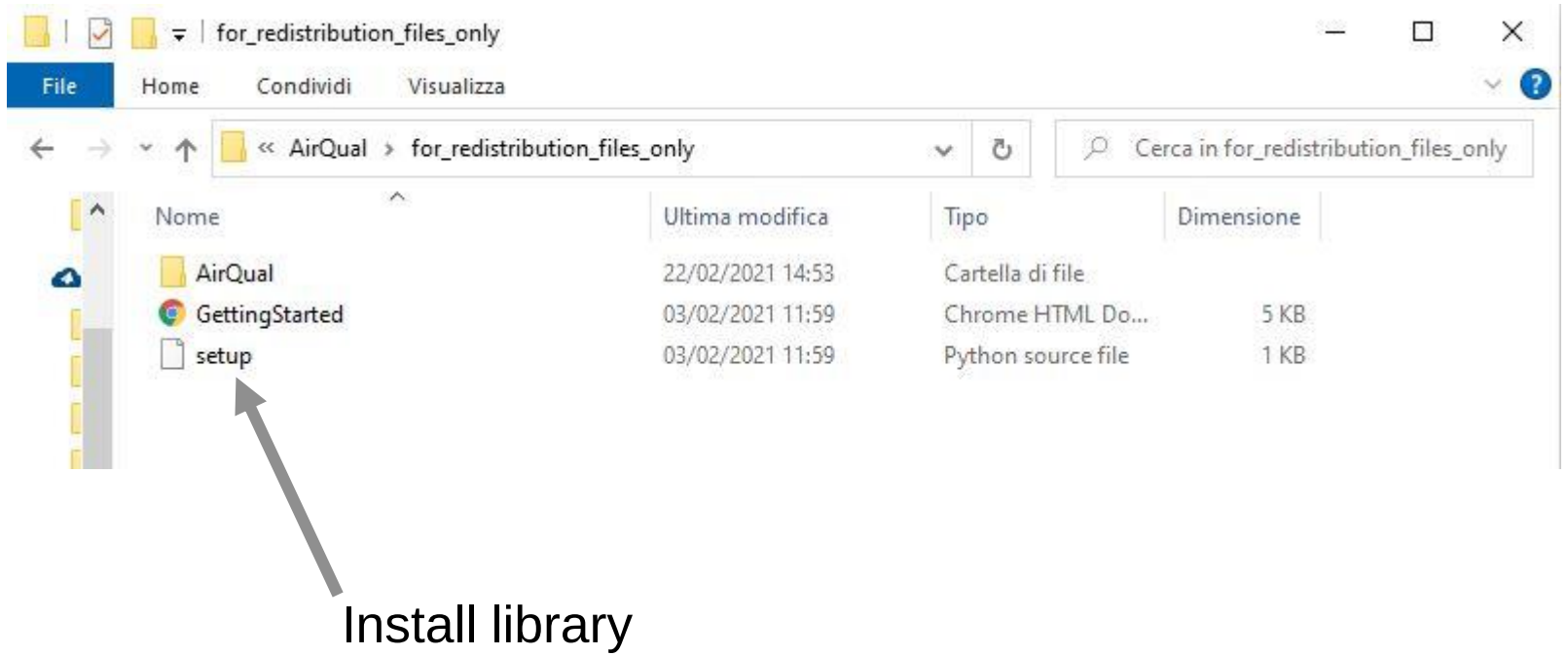
Co-Execution

- Call Python from MATLAB
- Call MATLAB from Python

Deployment

Generate Python library from MATLAB functions





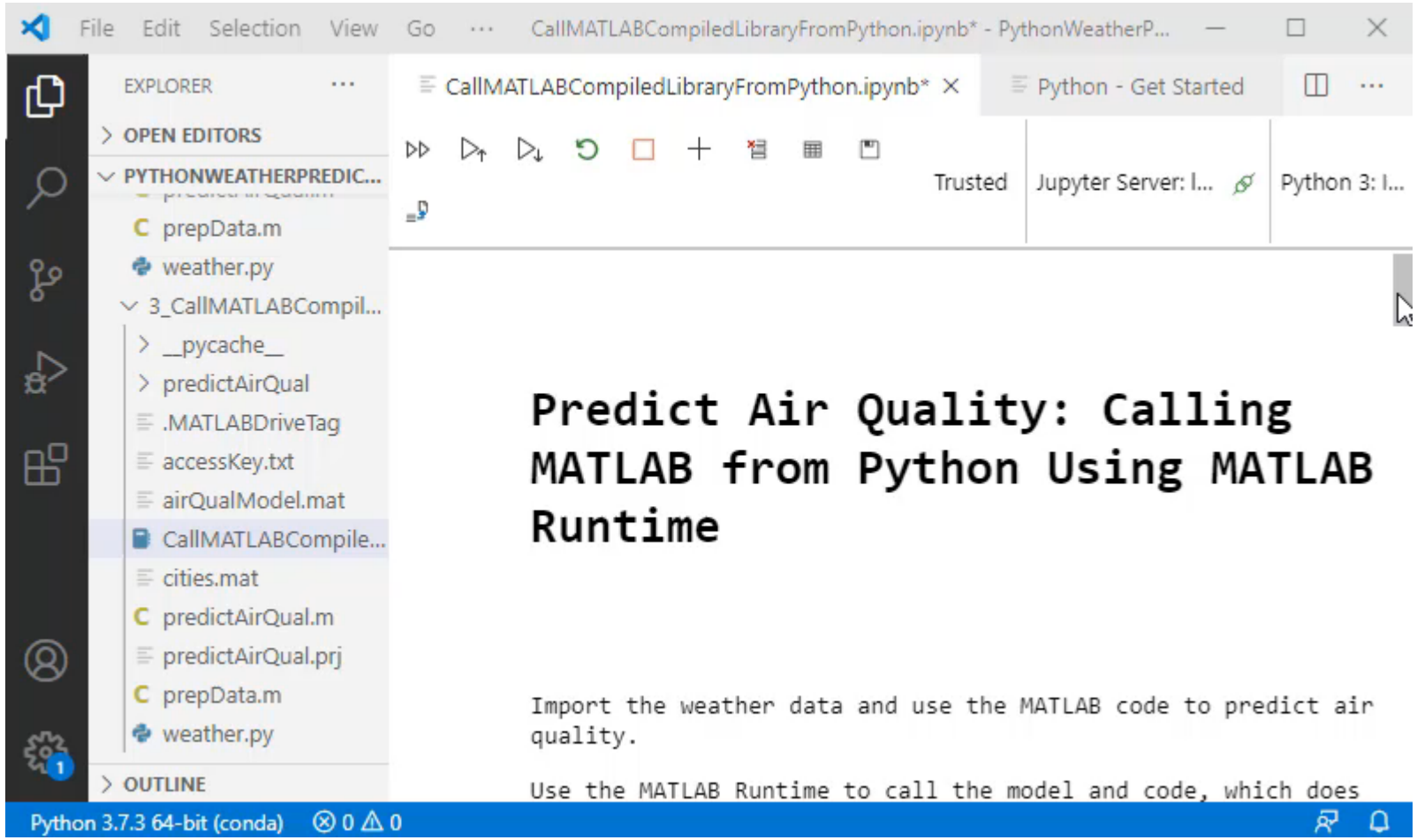
Execute Python library from MATLAB functions

Data Access

Co-Execution

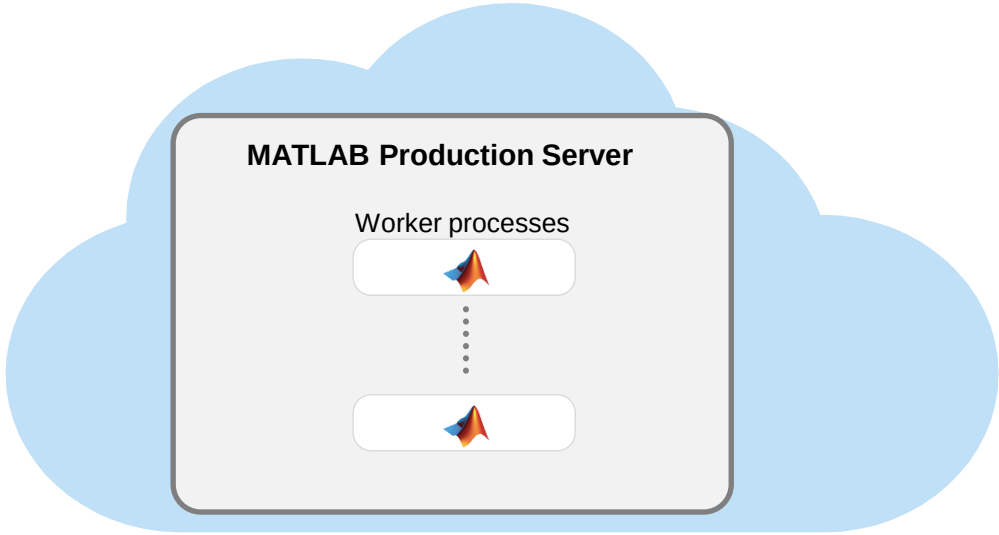
- Call Python from MATLAB
- Call MATLAB from Python

Deployment



MATLAB Production Server

Access functions as web services



Calling our function:

```
{"nargout":1,"rhs":["input"]}
```

Getting the result:

```
{"lhs":[{"mwdata":["output"],"mwsize":[1,6],"mwtype":"char"}]}
```

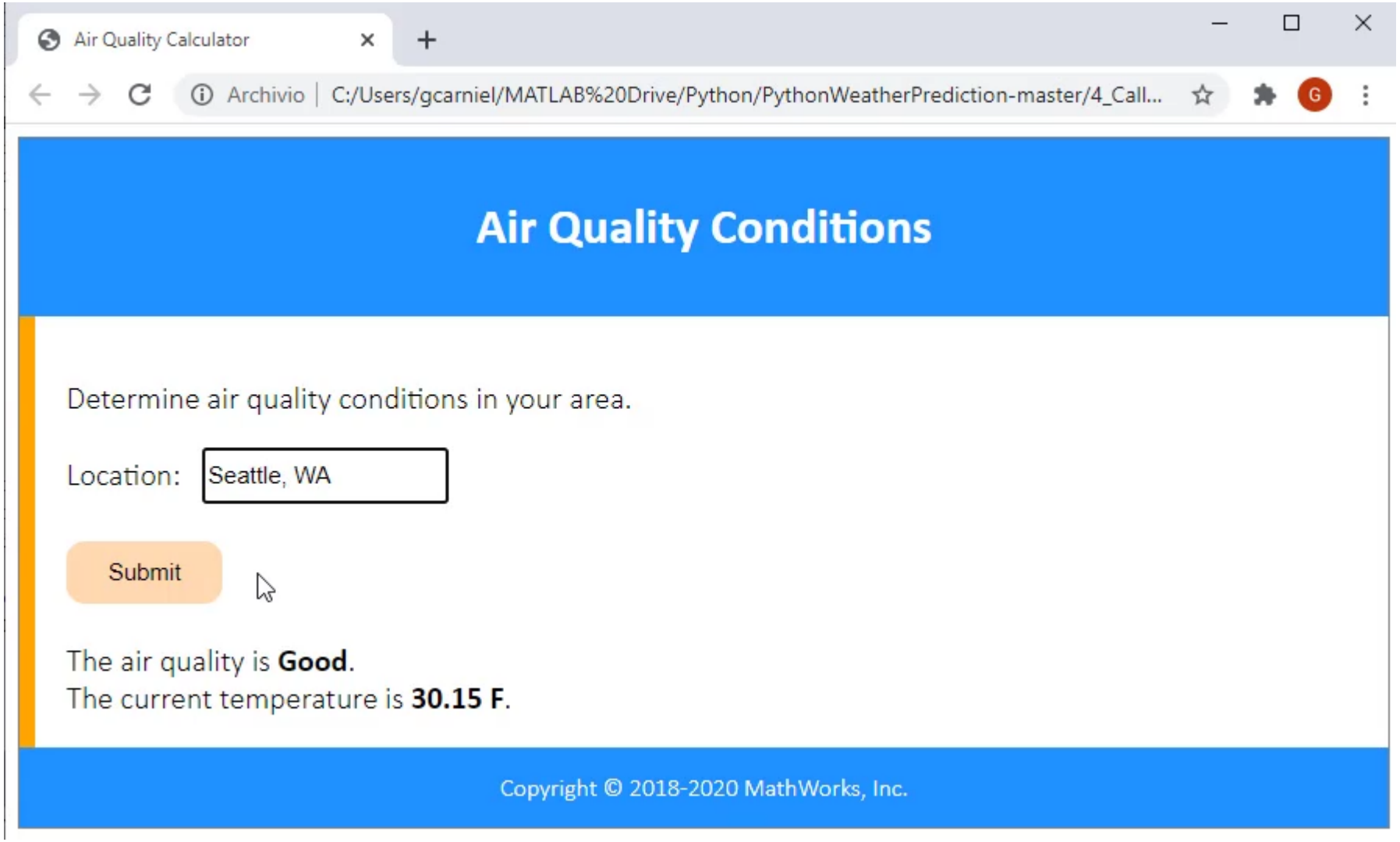
Execute Python library from MATLAB functions

Data Access

Co-Execution

- Call Python from MATLAB
- Call MATLAB from Python

Deployment



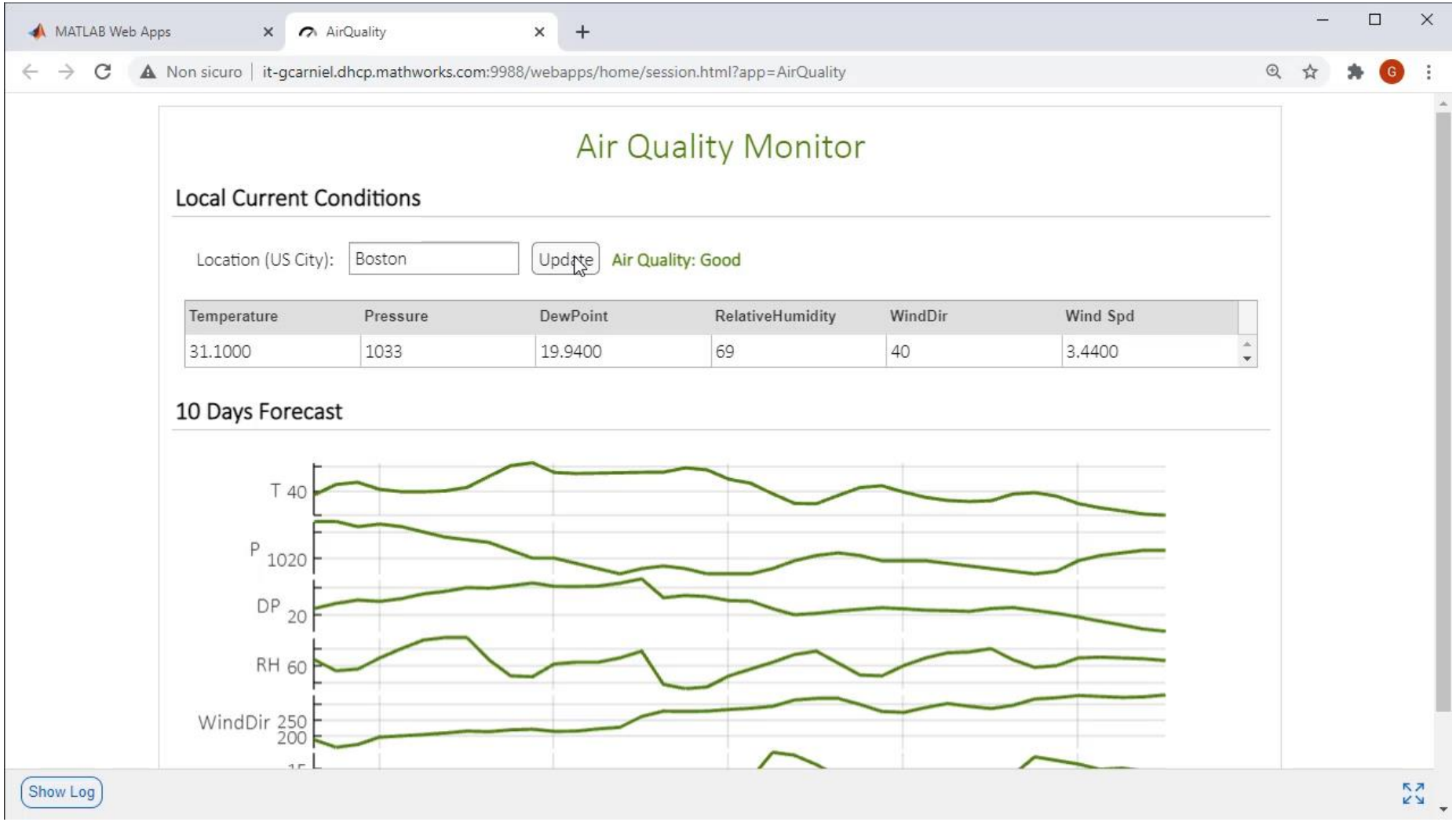
Share MATLAB App in the Web – Central Deployment

Data Access

Co-Execution

- Call Python from MATLAB
- Call MATLAB from Python

Deployment



Data Access

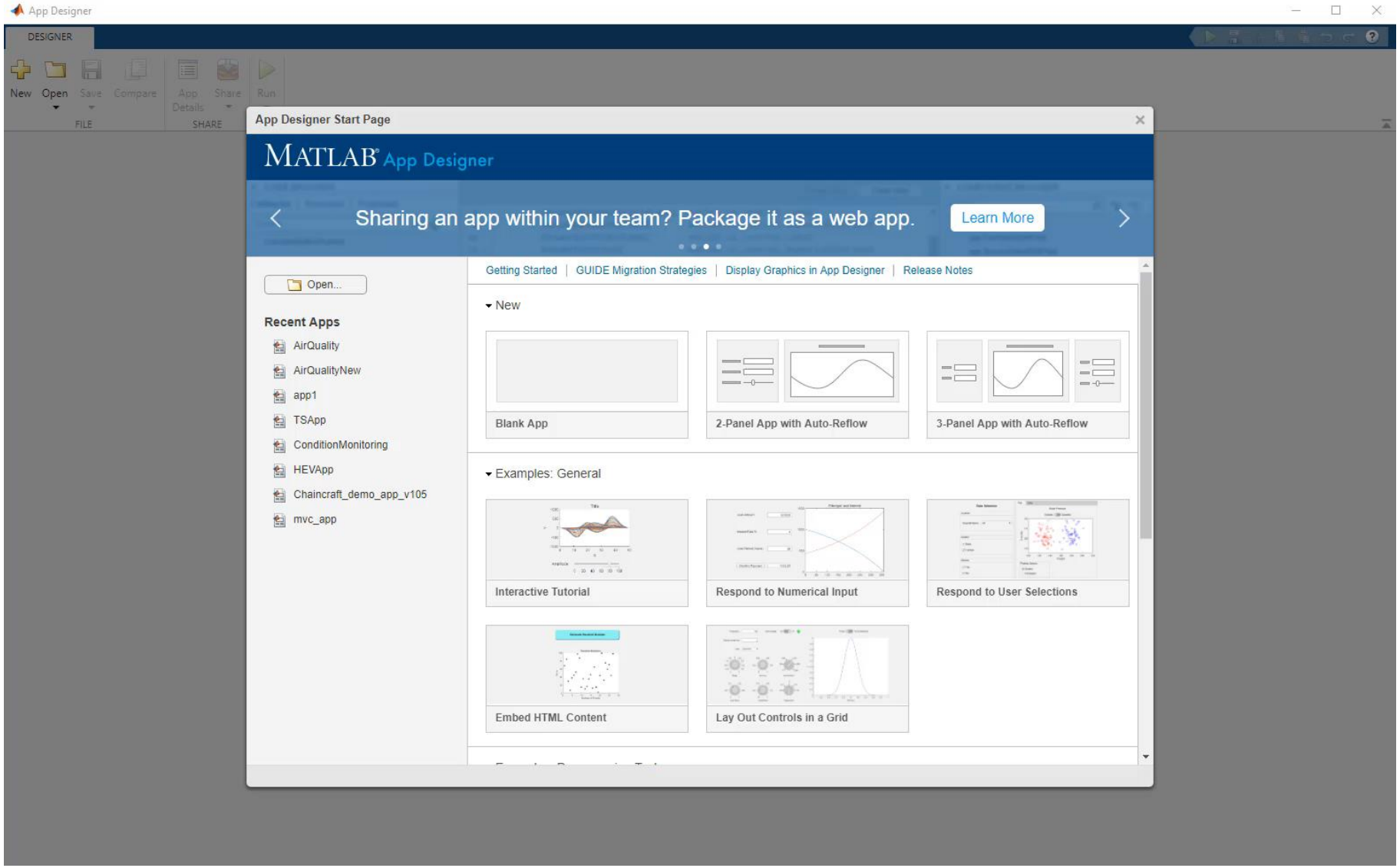
Co-Execution

- Call Python from MATLAB
- Call MATLAB from Python

Deployment

MATLAB App Designer

App development for Non-Programmers



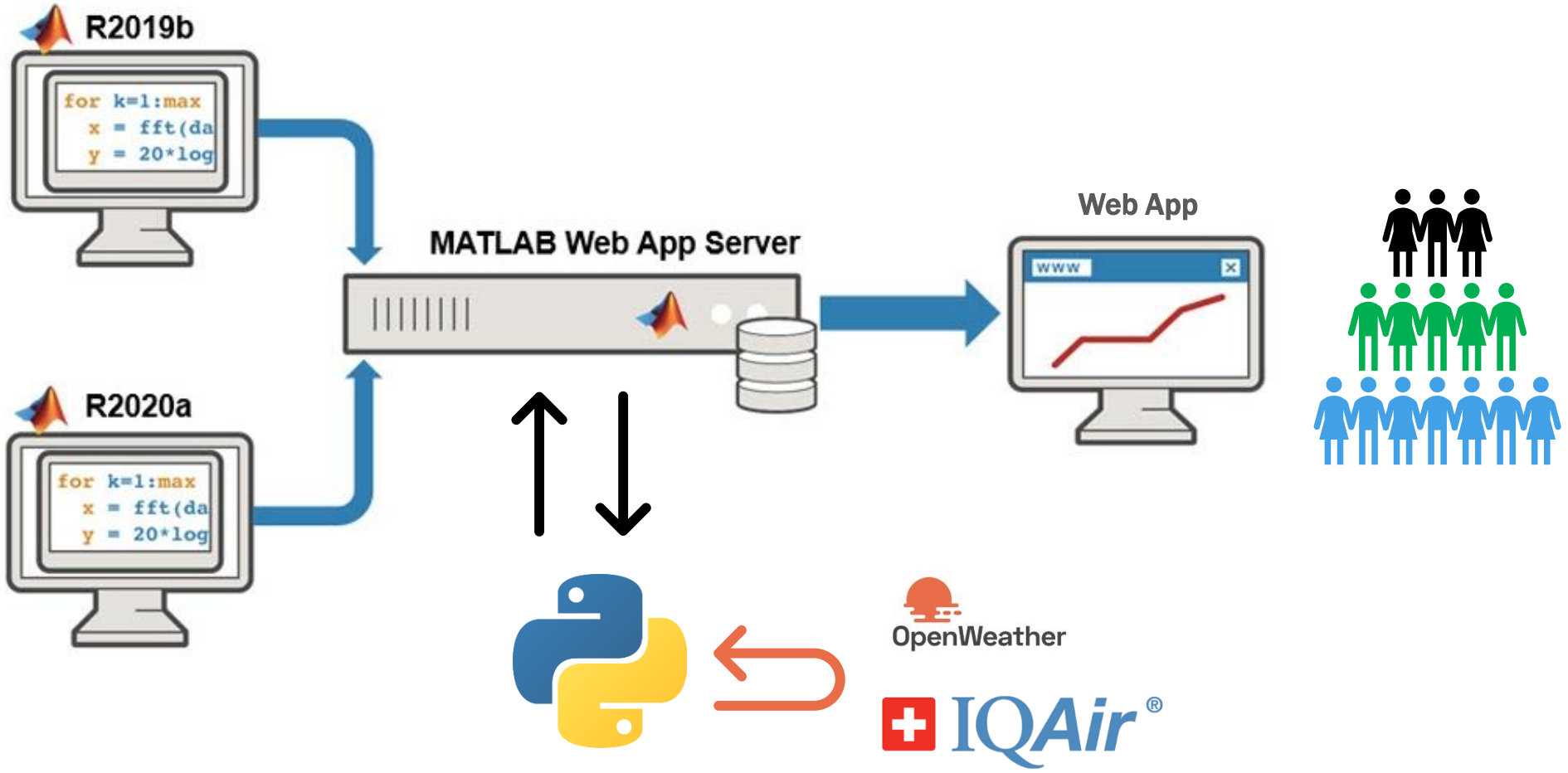
MATLAB Web App Server – Central Deployment

Data Access

Co-Execution

- Call Python from MATLAB
- Call MATLAB from Python

Deployment



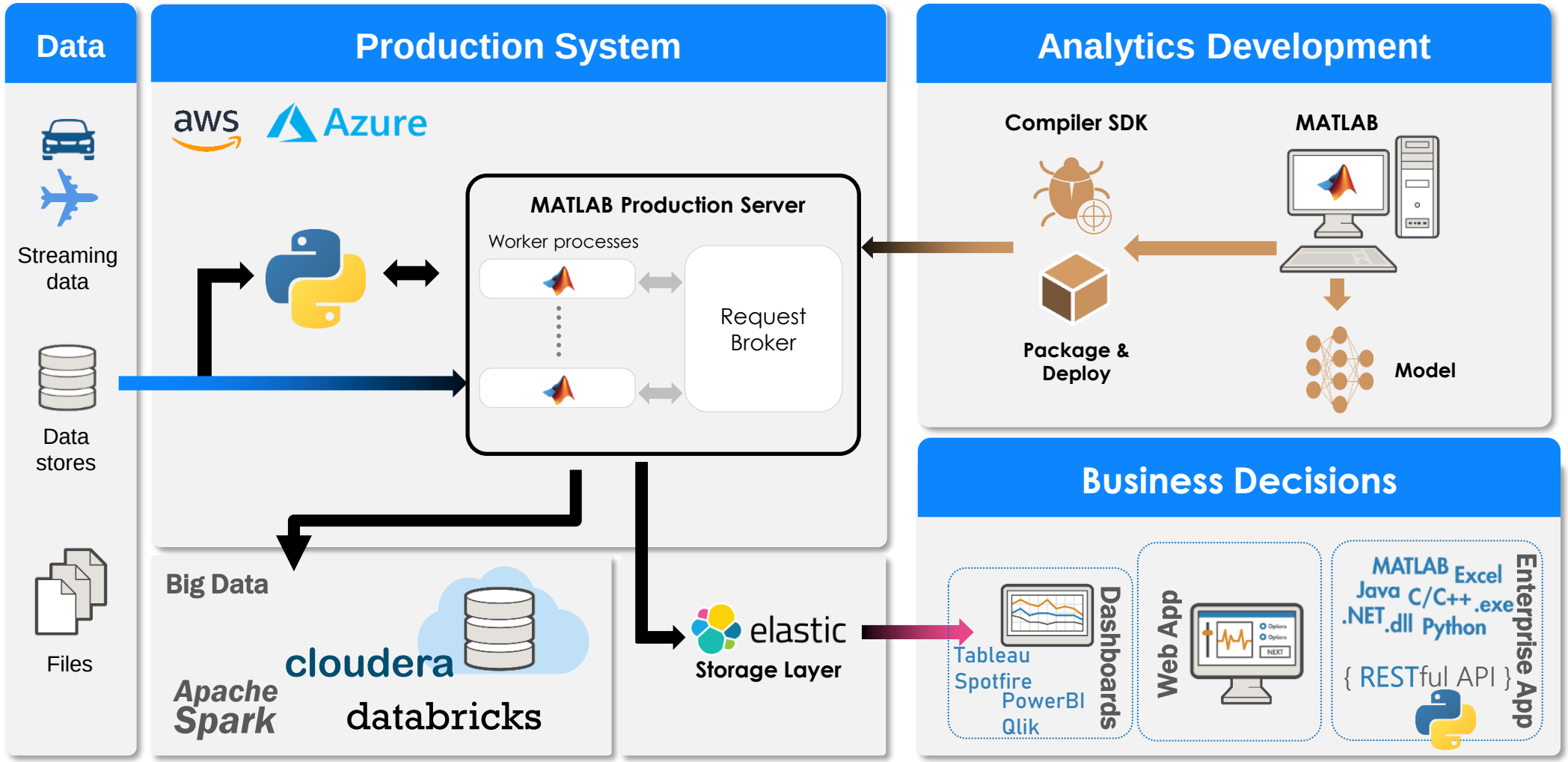
Integrate your Production System in an IT ecosystem

Data Access

Co-Execution

- Call Python from MATLAB
- Call MATLAB from Python

Deployment



Data Access

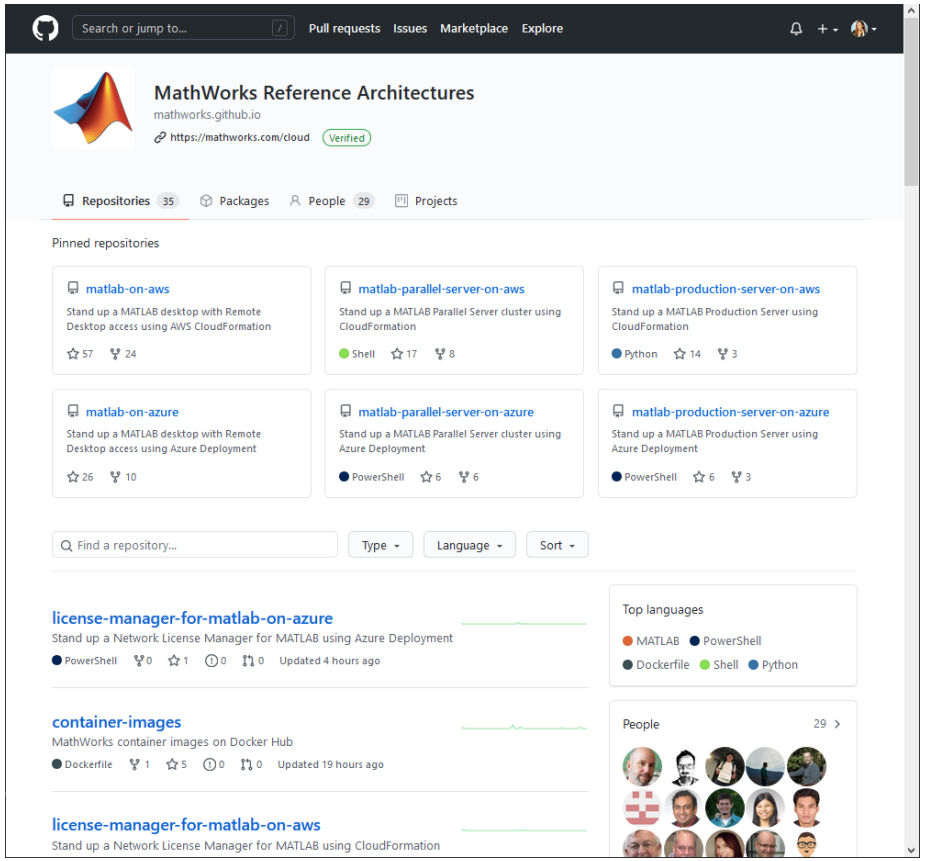
Co-Execution

- Call Python from MATLAB
- Call MATLAB from Python

Deployment

Use MATLAB Reference Architectures for easy cloud setup, Dockerfiles, and interfaces to OSS

- https://github.com/mathworks-ref-arch/matlab-dockerfile



https://github.com/mathworks-ref-arch

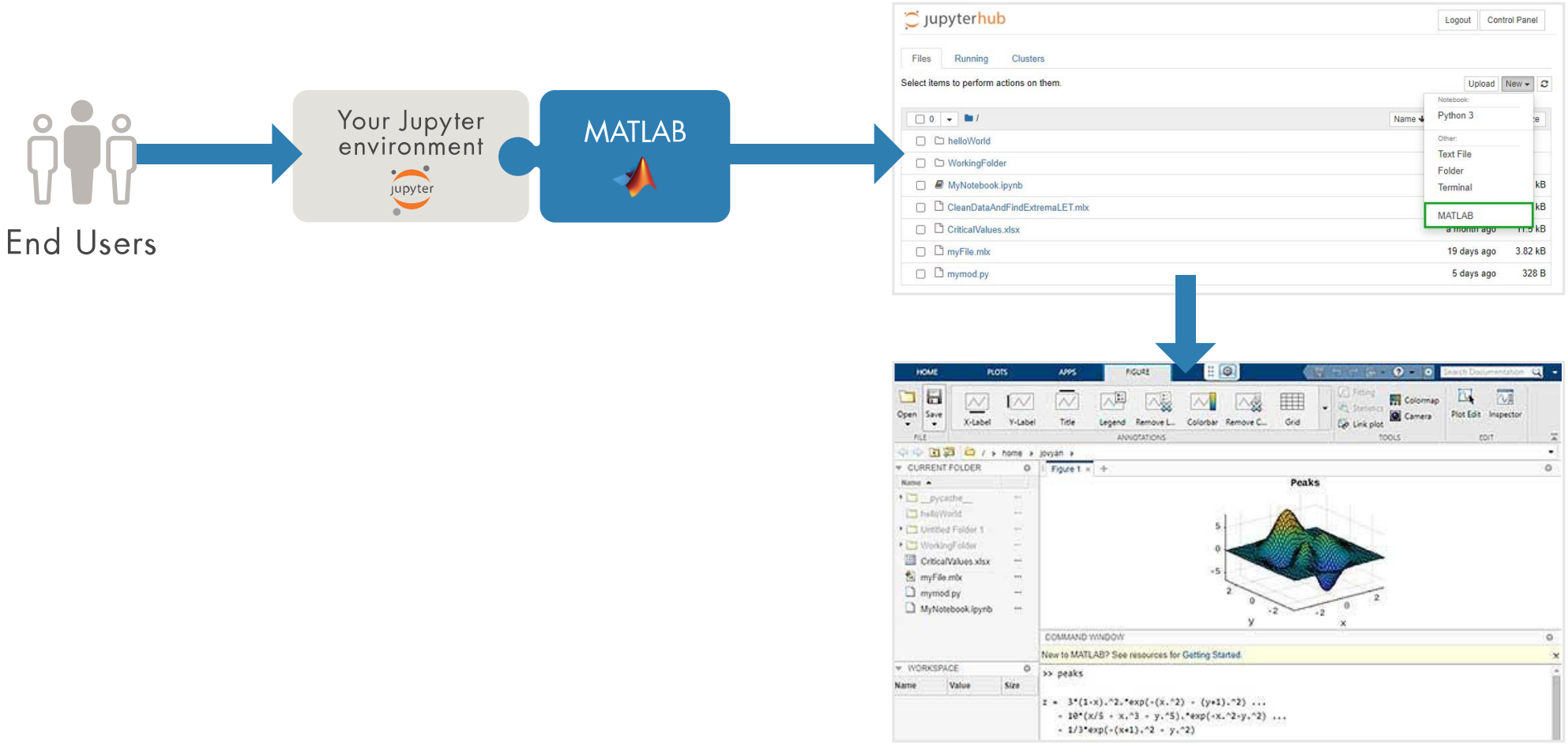
MATLAB Integration for Jupyter

Data Access

Co-Execution

- Call Python from MATLAB
- Call MATLAB from Python

Deployment



[MATLAB Integration for Jupyter (mathworks.com)]

Data Access

Co-Execution

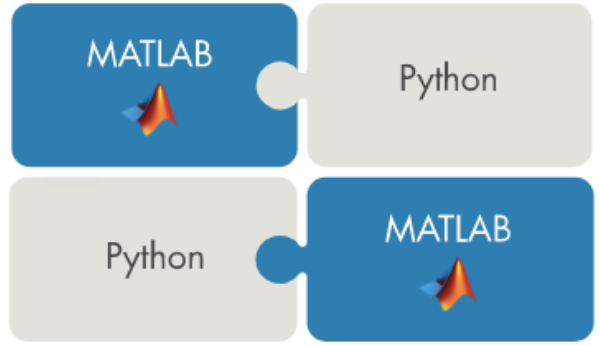
- Call Python from MATLAB
- Call MATLAB from Python

Deployment

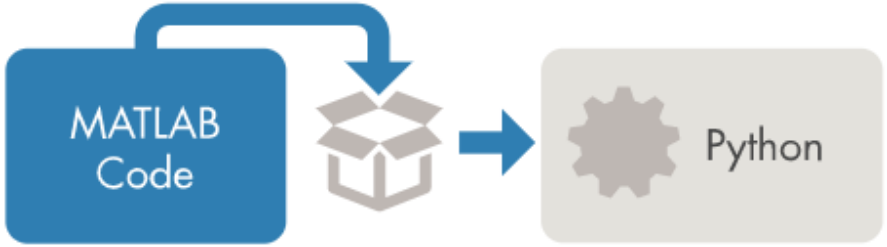
Summary:
Using MATLAB with Python

- Access Data
  - Weather App example

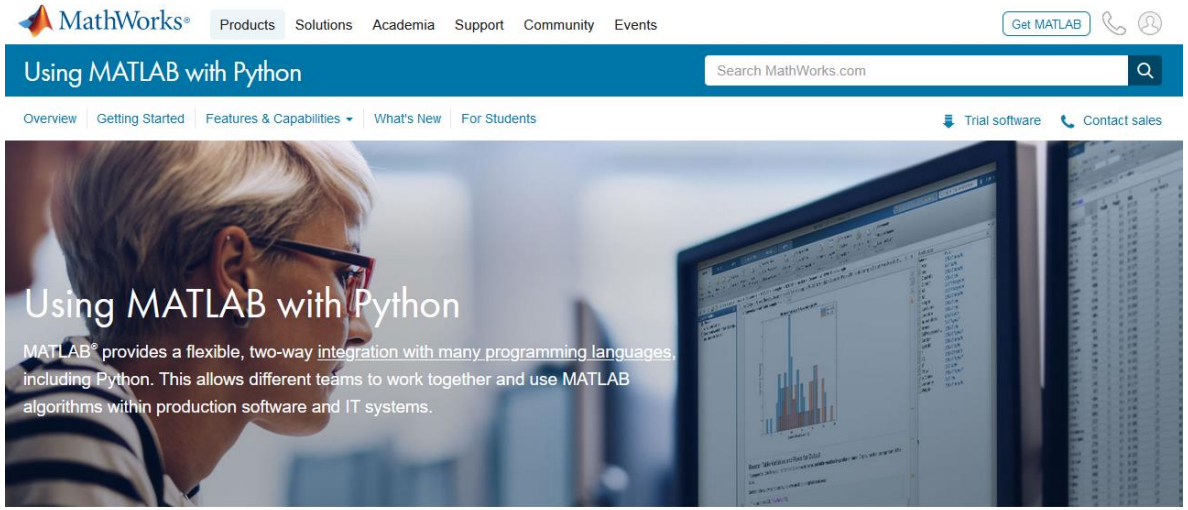
- Interoperability
  - Calling libraries written in Python from MATLAB
  - Calling MATLAB from Python

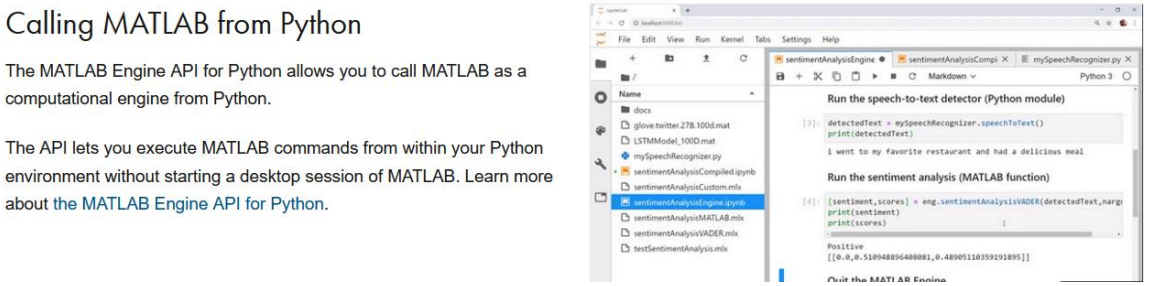


- Deploy Apps & Algos
  - Web App
  - Production API



Resources



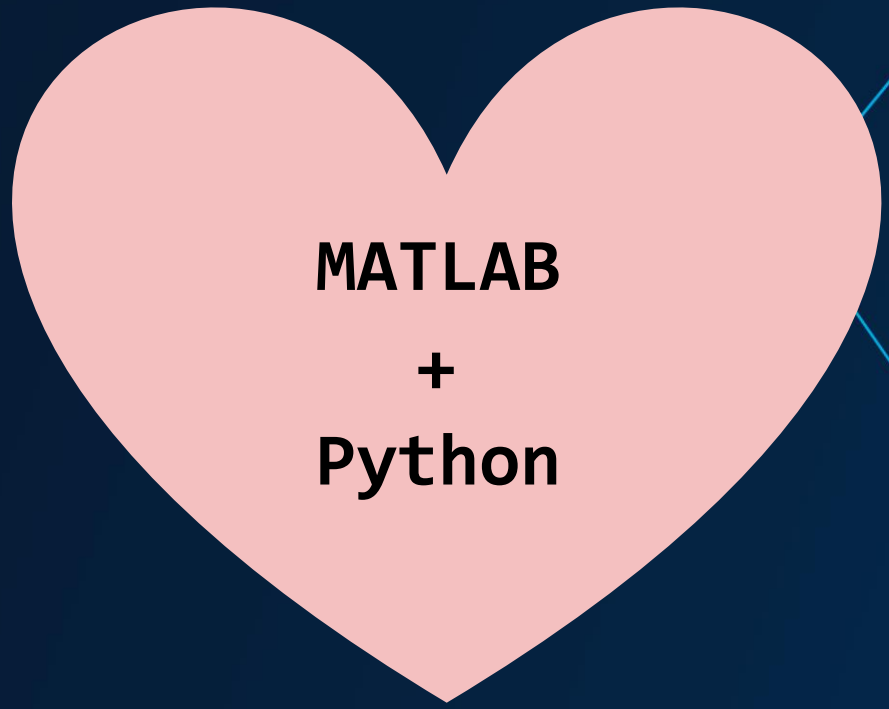


https://www.mathworks.com/products/matlab/matlab-and-python.html

- Cheatsheet
- Example on GitHub
- Blog post
- Videos
  - Calling Python from MATLAB
  - Calling MATLAB from Python
  - Using MATLAB with Python + Q&A (YouTube live stream recording)
- Documentation
  - Calling Python from MATLAB
  - Calling MATLAB from Python via:
    - MATLAB Engine API
    - MATLAB Compiler SDK
    - MATLAB Production Server
  - Data management:
    - Data type conversions
    - Working with Parquet files
    - MATLAB library for Apache Arrow on GitHub
  - Deep Learning (TensorFlow, PyTorch, etc)

MATLAB EXPO 2021

Thank you



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