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Plotly-Dash Interactive Mapping

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David McCracken Follow

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Using Dash-Leaflet & TiTiler

Originally published on PY_WRAM — Python for Wind Resource Assessment and Metocean.

Following on from an article written by the team over at Plotly "**5 Awesome Tools to Power Your Geospatial Dash App**" (5 Awesome Tools to Power Your Geospatial Dash App | by plotly | Plotly | Jul, 2022 | Medium) by Hannah Ker , Elliot Gunn & Rob Calvin. I wanted to expand on this by outlining some of my experiments with Plotly-Dash for use with geospatial apps and analysis using Python.

The What, How & Why

So what am I aiming to do, how do I want to do it and why ?

The What : I want to explore a very specific problem. How to use a large GeoTIFF dataset from the Global Wind Atlas (GWA) and view this on an interactive "slippy" map (think google maps) which allows me to explore the data. The app should allow me to see the data via a pop up or click event(in this case display the wind speed at a location the user clicks on).

The How: I want to achieve my interactive map by using the fantastic Plotly / Plotly Dash framework & Python. Ultimately this is a building block to a more detailed analytical app …but sometimes the building blocks deserve there own article.

The Why: The dataset I want to view is large (more about that later) so this makes it a challenging task . Also, the geospatial community in Python is brilliant and thriving but it can also sometimes feel impenetrable. This article will aim to explore just one method and how it was achieved but in a fair amount of detail , with the aim it can be followed by other relative novices like myself.

The Data

Lets discuses the data I am trying to view / analyse :

The data I want to view comes from the Global Wind Atlas v3.1(GWA).

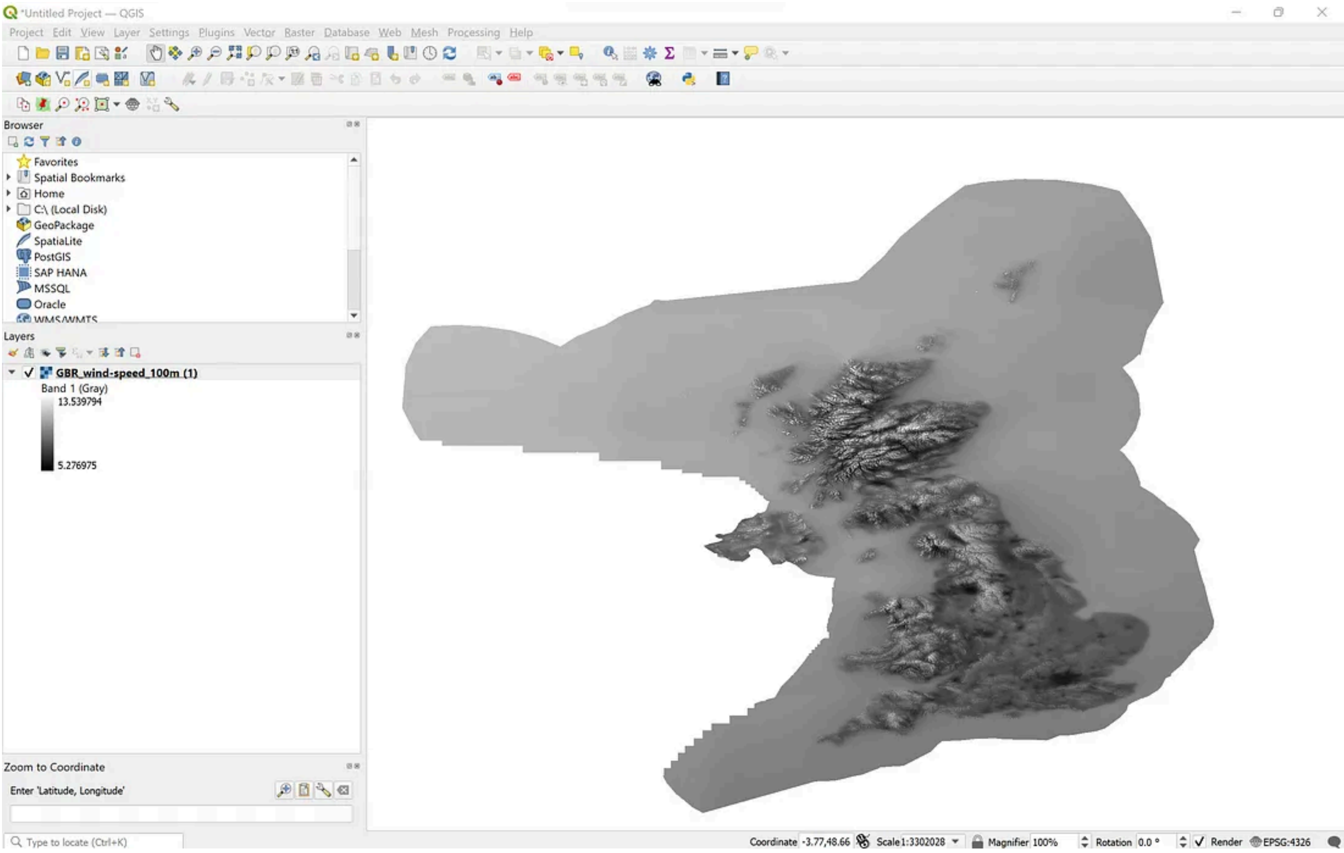
> GWA is a free, web-based application developed, owned and operated by the Technical University of Denmark (DTU). The Global Wind Atlas is released in partnership with the World Bank Group, utilizing data provided by Vortex, using funding provided by the *Energy Sector Management Assistance Program (ESMAP). For additional information: https://globalwindatlas.info*

Specifically the data Iam using is wind speed at 100m AGL for the United Kingdom that has been downloaded as a GeoTIFF. I am not going to go into how this data is created (but if interested this can be found here on the GWA website) but I will explain what this data looks like.

The GWA GeoTIFF for the UK consists of wind speeds on a 250m grid for the entire UK . Therefore this GeoTIFF is a grid of data with a width of 7315 points by a height of 6368 points (i.e a lon/ lat / Wind Speed grid). If we converted this data into a Pandas Dataframe then we would have 46.5 million rows (7315 x 6368). So it is a considerable amount of data!

Furthermore , this is just for the UK . The GWA provides data for the rest of the world also, which we may want use in the future. So ideally we are going to need a solution that scales beyond what we are using in this example. If we were to simply plot these data on a map as a simple GeoTIFF then chances are we would likely crash our browser.

Once downloaded we can view this data in a GIS package such as QGIS (I should note we could also do analysis in this package and view the data on a interactive background map even, but that doesn't allow us to use this in an app so I am not going to focus on that here).



GWA Wind Speed Geotiff viewed in QGIS (image by author)

The Tools and Libraries

Plotly-Dash & Dash Leaflet

One of the major advantages of Plotly-Dash is its community, and its community components . When it comes to mapping/geospatial analysis one of the best is Dash-Leaflet developed and maintained by Emil Eriksen. This component brings the popular Javascript Leaflet library into the Python world via Plotly.

*[**Side Note:** Dash-Leaflet has a built in method of seeing a Geotiff on a interactive map already ported over by Emil, called GeoTIFFOverlay . However , as noted above given the*

size of the dataset this method will result in a crash as our system will run out of memory — for smaller data sets however this may be a more appropriate method than the method discussed here.]

TiTiler — The Tile Server

Given we have established its a big data set we want to work with, we need a way to break down our data so that it can be presented in our browser. In order to achieve this we will use the brilliant package TiTiler. TiTiler is a modern tile server built on top of FastAPI and Rasterio/GDAL.

TiTiler's job is to take a type of Geotiff (called a Cloud Optimised GeoTIFF) and "serve" this to our interactive map. For this example, I will be using TiTiler running in Docker Desktop on my Local Host but it is equally possible to deploy it on a cloud platform like AWS , Azure etc for production(see TiTiler docs for more info).

Cloud Optimised Geotiff (COG)

The key to all of this is really a file type called Cloud Optimized GeoTIFF (COG). A COG is a regular GeoTIFF file, aimed at being hosted on a HTTP file server, with an internal organization that enables more efficient workflows on the cloud. It does this by leveraging the ability of clients issuing HTTP GET range requests to ask for just the parts of a file they need.

cogeo.org explains the techniques that Cloud Optimized GeoTIFFs use, namely *Tiling* , *Overviews* , *HTTP GET Requests* and *how these work together* to make Cloud Optimised GeoTIFFs work. This is summarised below but please check cogeo.org for further info:

> ***Tiling** creates a number of internal 'tiles' inside the actual image, instead of using simple 'stripes' of data. With a stripe of data then the whole file needs to be read to get the key piece. With tiles much quicker access to a certain area is possible, so that just the portion of the file that needs to be read is accessed.*
>
> ***Overviews** create downsampled versions of the same image. This means it's 'zoomed out' from the original image — it has much less detail (1 pixel where the original might have 100 or 1000 pixels), but is also much smaller. Often a single GeoTIFF will have many overviews, to match different zoom levels. These add size to the overall file, but are able to be served much faster, since the renderer just has to return the values in the overview instead of figuring out how to represent 1000 different pixels as one.*

> ***HTTP*** *Version 1.1 introduced a very cool feature called Range requests. It comes into play in GET requests, when a client is asking a server for data. If the server advertises with an* `Accept-Ranges: bytes` *header in its response it is telling the client that bytes of data can be requested in parts, in whatever way the client wants. This is often called Byte Serving, and there's a good [wikipedia] article explaining how it works. The client can request just the bytes that it needs from the server. On the broader web it is very useful for serving things like video, so clients don't have to download the entire file to begin playing it.*
>
> *The Range requests are an* optional *field, so web servers are not required to implement it. But most all the object storage options on the cloud (Amazon, Google, Microsoft, OpenStack etc) support the field on data stored on their servers. So most any data that is stored on the cloud is automatically able to serve up parts of itself, as long as clients know what to ask for.*
>
> ***Bringing them together***
>
> *Describing the two technologies probably makes it pretty obvious how the two work together. The Tiling and Overviews in the GeoTIFF put the right structure on the files on the cloud so that the Range queries can request just the part of the file that is relevant.*

Pre-Processing & Set up

Converting Geotiff to Cloud Optimised Geotiff

When we download the GeoTIFF from Global Wind Atlas this is not in the required Cloud Optimised GeoTIFF format. As such, we need to convert this — to do this we will use the Package rio-cogeo. We are going to use the **Command line Interface,** However we still need to install rio-cogeo, this is done as usual, using pip in your terminal(i.e. `pip install rio-cogeo`).

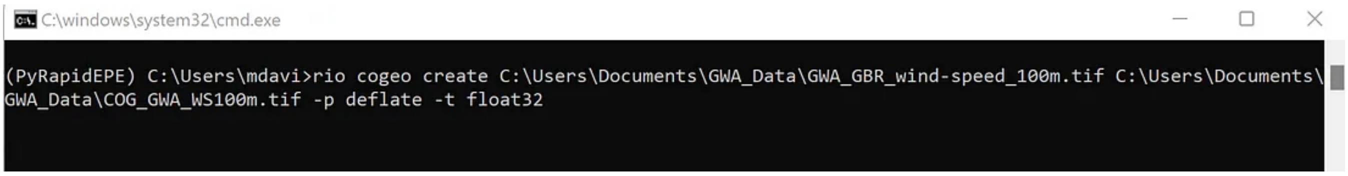
To convert our geotiff to a cloud optimised geotiff , we should open a new terminal in the Python environment you installed rio-cogeo and run the `rio cogeo create` command.

This command takes the following inputs in the order specified:

- The original GeoTIFF file location — i.e. the downloaded GeoTIFF from GWA. `C:\Users\Documents\GWA_Data\GWA_GBR_wind-speedP100m.tif` .

- The output file location (and name) — i.e. where we will write the file to. `C:\Users\Documents\GWA_Data\COG_GWA_WS100m.tif`
- Any Options you wish to use (see here) in my case the output compression **Profile** *"deflate"* `-p deflate` & **Data Type of output (-t)** *"float 32"* `-t float32` (as we are exporting wind speed and I wish to keep the decimal point we need to keep the data as a float32)

As such the command window looks like below:



Rio-Cogeo **Command Line Interface** method. (Image by author)

Assuming everything has run correctly you should now have a Cloud Optimised Geotiff called `COG_GWA_WS100m`.

AWS S3 Upload

As noted above , we need to store the data in a place that can accept a **GET Request** . In this instance I will be using an **AWS S3 bucket** . We need to upload the COG and copy the ***object URL*** for use later . Depending on how you have set up your AWS S3 bucket , you may need to use the `BOTO3` package. You could also use Google cloud storage or digital ocean etc for storage of the COG. Once uploaded and the Object URL copied we can set up TiTiler.

TiTiler set up

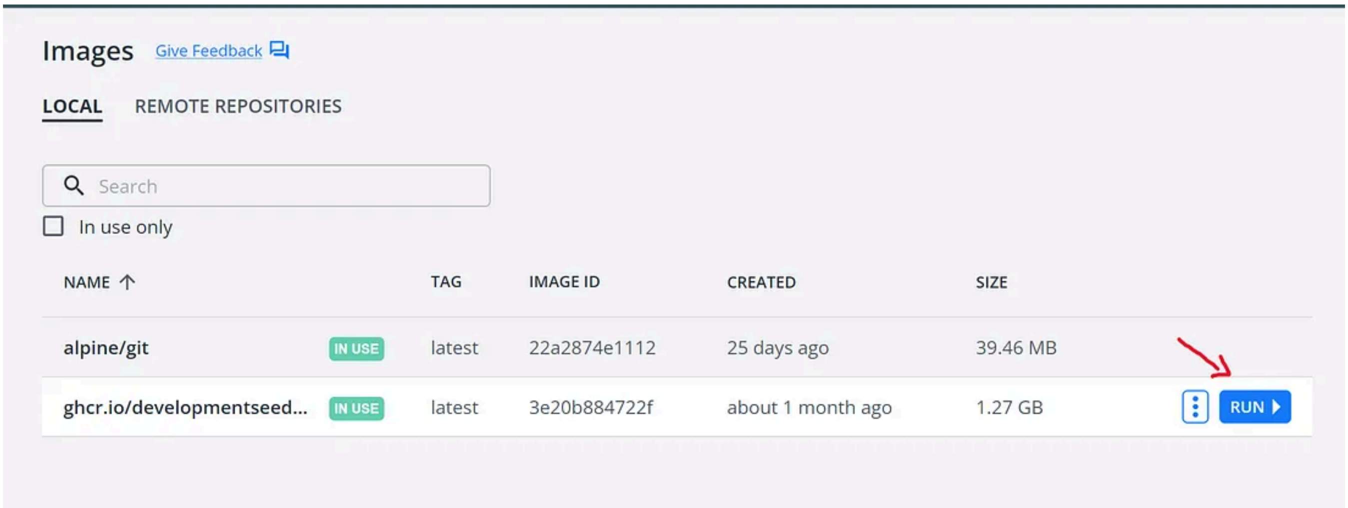
TiTler is the Tile server we are going to use , this is going to *"serve up"* our COG file from the AWS S3 Bucket. However , we first need to deploy TiTiler , I have chosen to use the *Docker Image* referred to on the TiTiler docs and used Docker Desktop to do this , but you can use a multitude of different methods such as using uvicorn or even AWS Lambda.

Using TiTiler with Docker Desktop locally

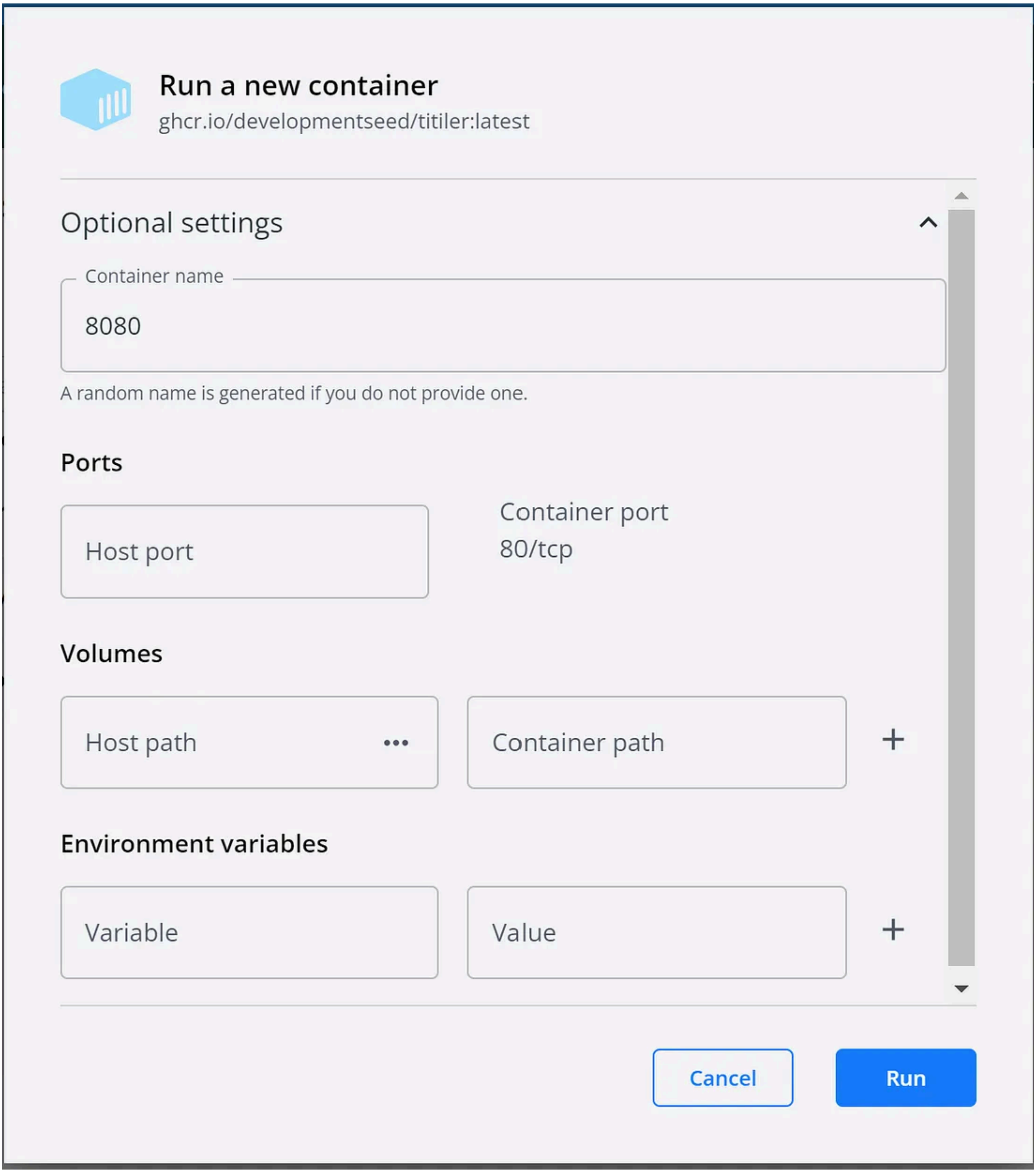
Install Docker Desktop if you have not already and use the command line to pull the image from Github:

```
> docker pull ghcr.io/developmentseed/titiler:latest
```

Once the image is pulled down it should appear in Docker Desktop, you will need to run the container and in the pop up select **optional settings** to enter the Local Host port you wish to run TiTiler on — in this case we will be using 8080 . This means that our TiTler endpoint will be running on `http://localhost:8080`

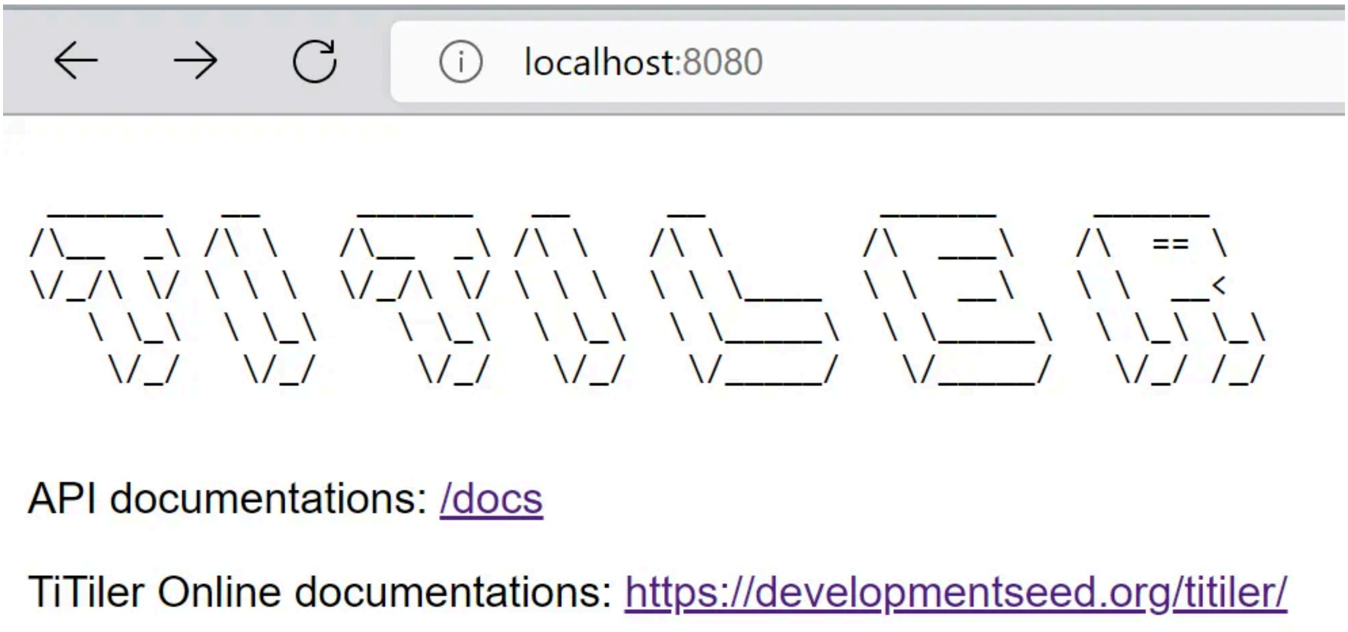


Click Run once image is pulled(Image by author)



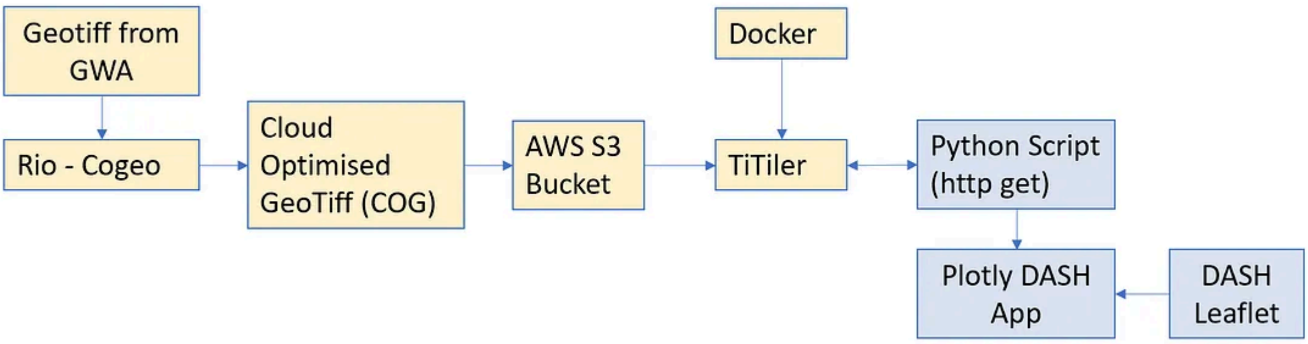
Optional settings change Ports to Local Host required (image by author)

To check TiTiler is running , open a web browser to `http://localhost:8080` and you should see something similar to below:



TiTiler running on local host 8080 (image by author)

The pre-processing and setup for creating our app is now complete. To summarise the work we have done so far , the yellow cells below outline the work and relationship between all the pre-processing steps. The next part of this article will now focus on the blue sections, which is the use of TiTiler in Plotly DASH.



Pre processing flow (Image by author)

Building Our Simple Map Application

Lets import the required libraries for building our app:

Import libraries for app (image by author)

We are building the app using Plotly-Dash so we are importing `Dash` . I am also importing a package called `JupyterDash` which is also made by Plotly. The `JupyterDash` package simply allows us to create our Dash App in a Jupyter-Notebook , which is my preferred way of working. We also import `dash_leaflet` which is the component that brings the popular JavaScript Leaflet library into the Python world via Plotly.

The final two elements imported `json` and `httpx` will be used for getting data from TiTiler.

[Note: These libraries will have to be installed using `Pip` or `Conda` before they can be imported . I have skipped this step here.]

For TiTiler to work we need to provide it with two things:

1. The `TiTiler Endpoint` .
2. The `URL` to our Cloud Optimised GeoTIFF stored on AWS S3 .

For this example our `TiTiler endpoint` will be running on my local host (via Docker Desktop as above). I have saved `S3_URL` in a txt file here for privacy here but this is simply the ***Object URL*** noted above in the AWS S3 section.

set TiTiler endpoint & URL (Image by author)

With our `TiTiler Endpoint` and `URL` set we can start interacting with our Cloud Optimised GeoTIFF using GET requests by using `httpx.get`

As our data is stored in `Float 32` format, one of the first things we need to do is get and idea of the the `Max` and `Min` values in our data set. This is needed as we will need to `rescale` our tile map , if we did not do this our data would come back to us with a range of 0–255 (which would not make any sense) . Instead we need this data to be scaled to the wind speed `min` and `max` for it to make sense on the map once displayed.

This is achieved using `TiTiler cog/statistics` and extracting `min` and `max` from the returned dictionary item as below:

Get Min and Max wind speed (Image by author)

`minv` & `maxv` represent the `min` and `max` wind speed in our data set. We can use these in retrieving our tile map from TiTiler , which ensures that our data comes back in the required scale and will display correctly later.

Get tile map (Image by author)

If we look at the returned variable `r` from the above code in a variable viewer we would see a dictionary item , within which we will have an item called `"Tiles"` with a corresponding variable looking something like: `http://localhost:8080/cog/tiles/WebMercatorQuad/{z}/{x}/{y}@1x?url= S3_URL` **this is our tile map!**

Before we build our map using the above data from `TiTiler` , I want to just create one function which I will use on the map to display the wind speed at the location of a user click . I will again use a `httpx.get` function alongside the in-built TiTiler function `cog/point/{lon}/{lat}` .

*[**Note:** I have set the resampling to `average` which takes the distance weighted average of the nearest points , rather than say `nearest` , which simple takes the nearest value.]*

Create get point value function (Image by author)

This function simply runs a Get Request using the latitude and longitude it is passed
.

Building a Simple Dash App

So, above we have our code for getting the Tile Map & we have also created a function , whereby if we give it a latitude and longitude we will get a returned wind speed. That's the beginning of our app , so lets start bringing it all together.

For completeness I have copied the full app code below , I will break this down further in the proceeding sections but if you don't want or need to read that, then the below code will create a map using our Tile Map and allow you to click and get a wind speed displayed in an info panel.

Interactive App — full code (Image by author)

OK , lets break this down into the component parts:

Firstly , lets start with the very first line and the very last line of the code above, `app = JupyterDash(__name__)` and `app.run_server(debug=True,mode='inline')` .

These are component parts of any JupyterDash app and are the same as writing `app = Dash(__name__)` and `app.run_server(debug=True)` at the start and end of any other Dash app but simply changed a little because I am using `JupyterDash`.

Apart from changing Dash to JupyterDash , the only other thing to note is the extra command of `mode='inline'` in `app.run_server` . This simply tells JupyterDash to display the output of the app in the Jupyter Notebook rather than in our browser on localhost 8050 as is more common in regular Dash apps. (Note : if we did want to display the app in our browser but still wanted to use JupyterDash we would just change this to `mode='external'`)

The next section of code simply creates the `Info` panel we will display the wind speed in once the user clicks the map. This `info` panel is a simple `html.Div` with the position fixed to the bottom left of the map/app.

Create the info panel (Image by author)

The next section of code is the main part of our app. The app is really simple and only consists of a dash-leaflet map (`dl.map`)in a `html.Div` . There are two layers to the map , the `basemap` which is fed in as a Tilelayer using `dl.Tilelayer` and the COG from `TiTiler` we got using the `httpx.get` request which we assigned to the variable `r` . In the code we are extracting the `"tiles"` item from the returned dictionary and displaying this as a second Tilelayer (`dl.Tilelayer`).

The `dl.LayersControl` , `dl.Overlay` and `dl.LayerGroup` are all layer controls to that allow for user functionality such as allowing each layer to be turned on and off etc.

`dl.colorbar` simple shows a colour bar on the map using the previously calculated `minv` and `maxv` to provide the scale .

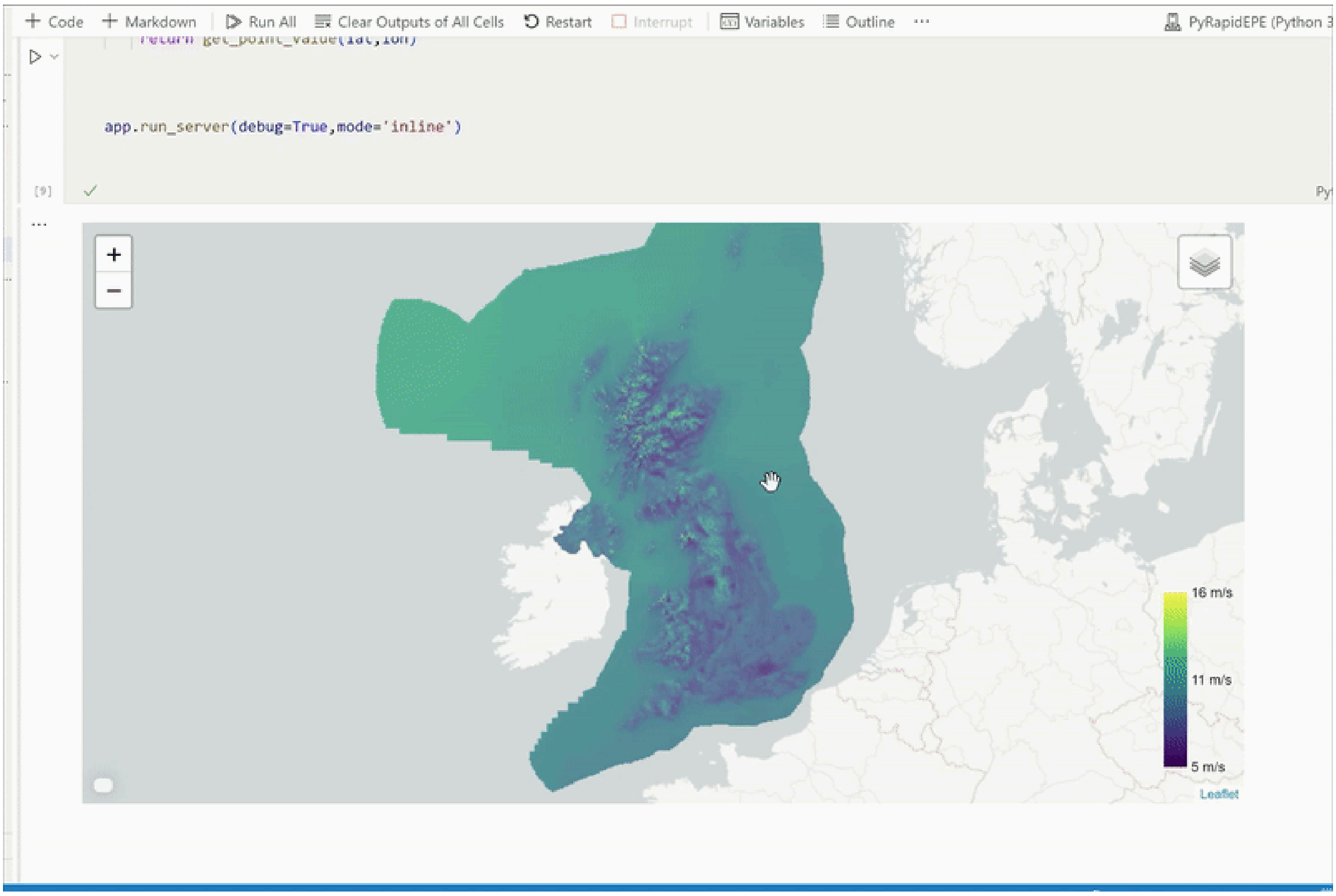
Create Dash app layout (Image by author)

Finally, we have the `@Callback` . The callback in a Dash app contains the code that is triggered on a `input` being triggered . This could be a slide of a slider a checkbox being checked and so on. In this case the `Input` is the click of our map by the user (`click_lat_lng`). The `output` of this callback is our `info` panel we built above as noted by the `id` matching that set in setting up the info panel above.

`click_lat_lng` is an inbuilt feature of Dash-Leaflet which provides the latitude and longitude of the click location. On clicking the map , the latitude and longitude is passed to the function we defined above `get_point_value` which retrieves the wind speed from that location, this in turn is then fed to the `output info` panel.

Dash Callback (Image by author)

All going well , you should see a map similar to the Gif below. Congratulations , This is a large GeoTIFF displayed in a Dash app using Dash-Leaflet and TiTiler.



Dash Leaflet & TiTiler displaying GWA data on interactive map (image by author)

Thanks for reading my article. The full Notebook for this guide can be found at link below:

Dash_Riotiler_Titiler/DashLeaflet_TiTiler.ipynb at 4b2ae6226aee5f43c2b804f9a568b3d3de94c796 ·...

Contribute to mdavid800/Dash_Riotiler_Titiler development by creating an account on GitHub.

github.com

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Wind Resource Analyst & Python geek. Founder of PY_WRAM-Python for Wind Resource Assessment & Metocean (www.pywram.com)

Responses (2)

Felipegenovese

What are your thoughts?

Matthew toberman
Feb 3, 2023

Thank you for a really clear , and helpful post! thanks to you I have something similar working now myself :) I just wanted to ask you if you had investigated any further with cog/point/{lon}/{lat}. I would really like to get multiple values from... more

1 Reply

Henrygilks
Feb 19, 2023

Great article, I have been working through the same problem using the same dataset and have been playing with datashader but this puts a lot of data in memory.

How can you use the tile server in a production version of the app?

Reply

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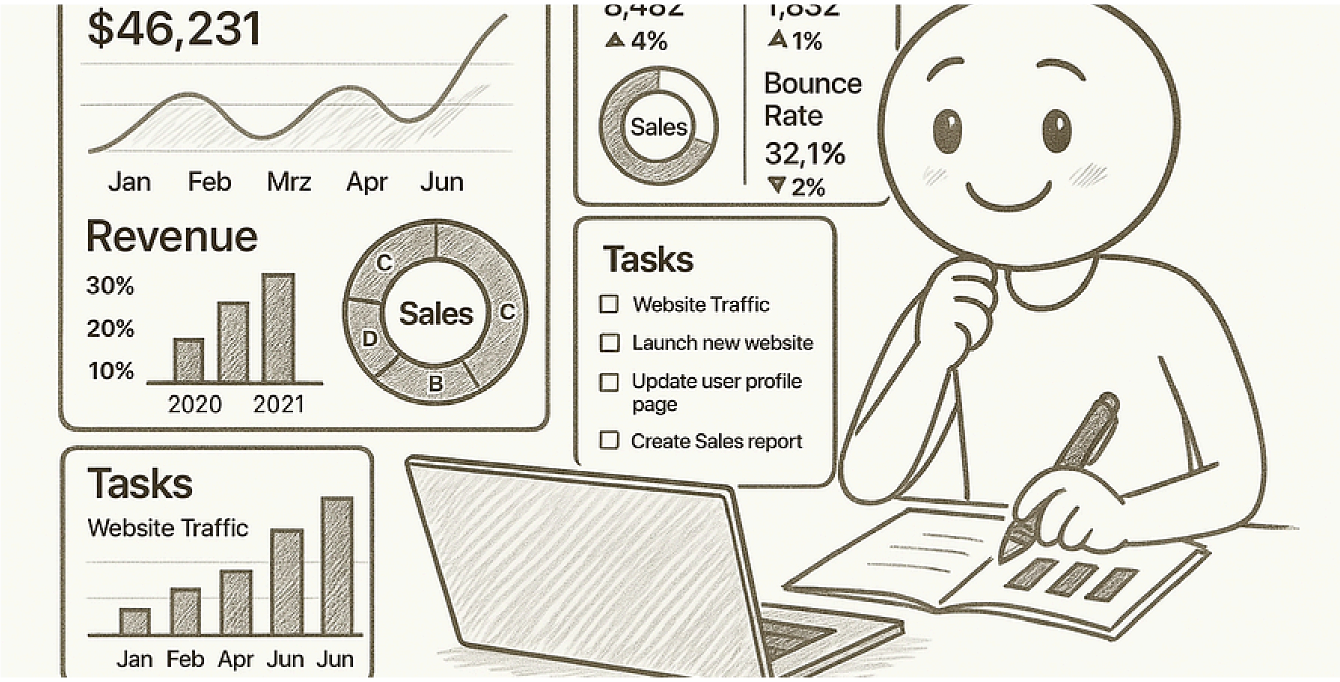

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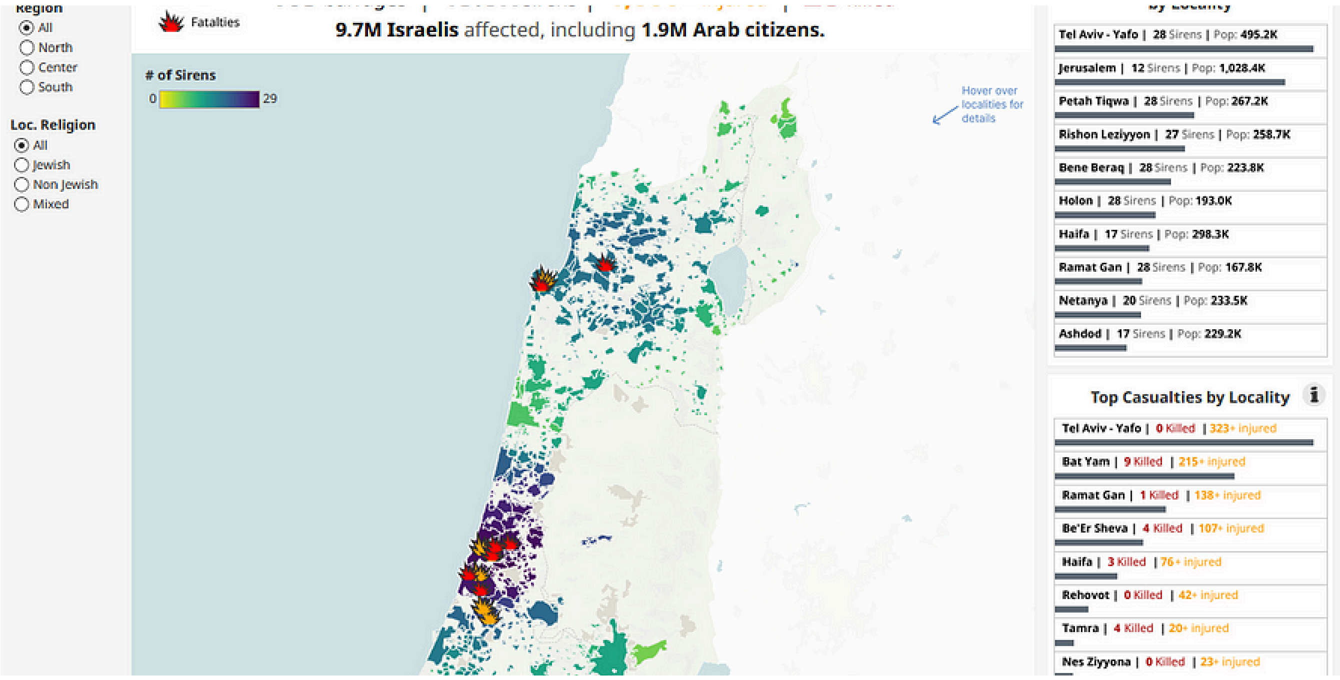

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