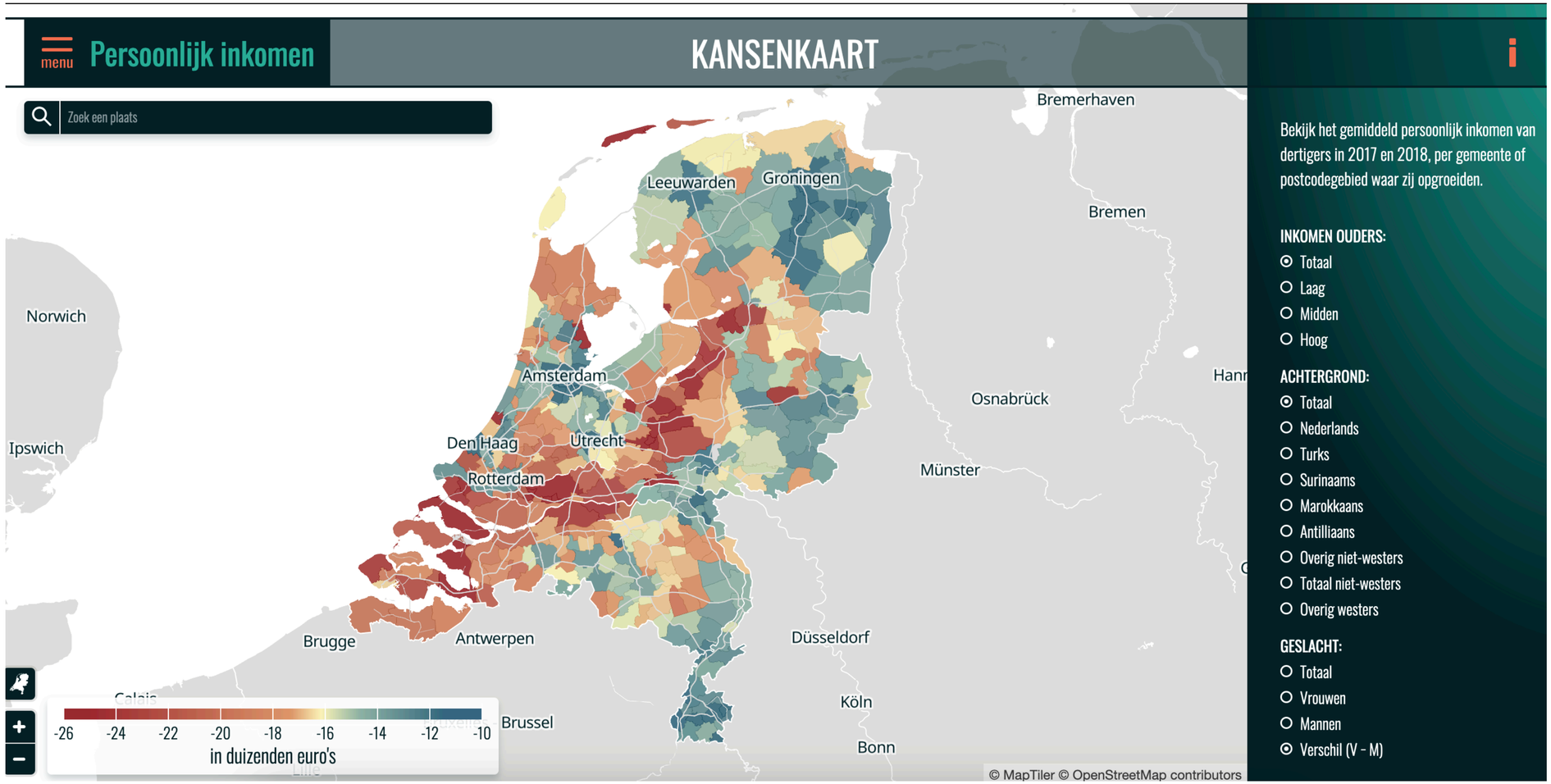
PART B

INTERACTIVE VISUALISATIONS AND (SERVERLESS) DASHBOARDS

WHY DO WE WANT INTERACTIVE VISUALISATIONS?

WHY DO WE WANT INTERACTIVE VISUALISATIONS?

Main use: Explore data



https://kansenkaart.nl/

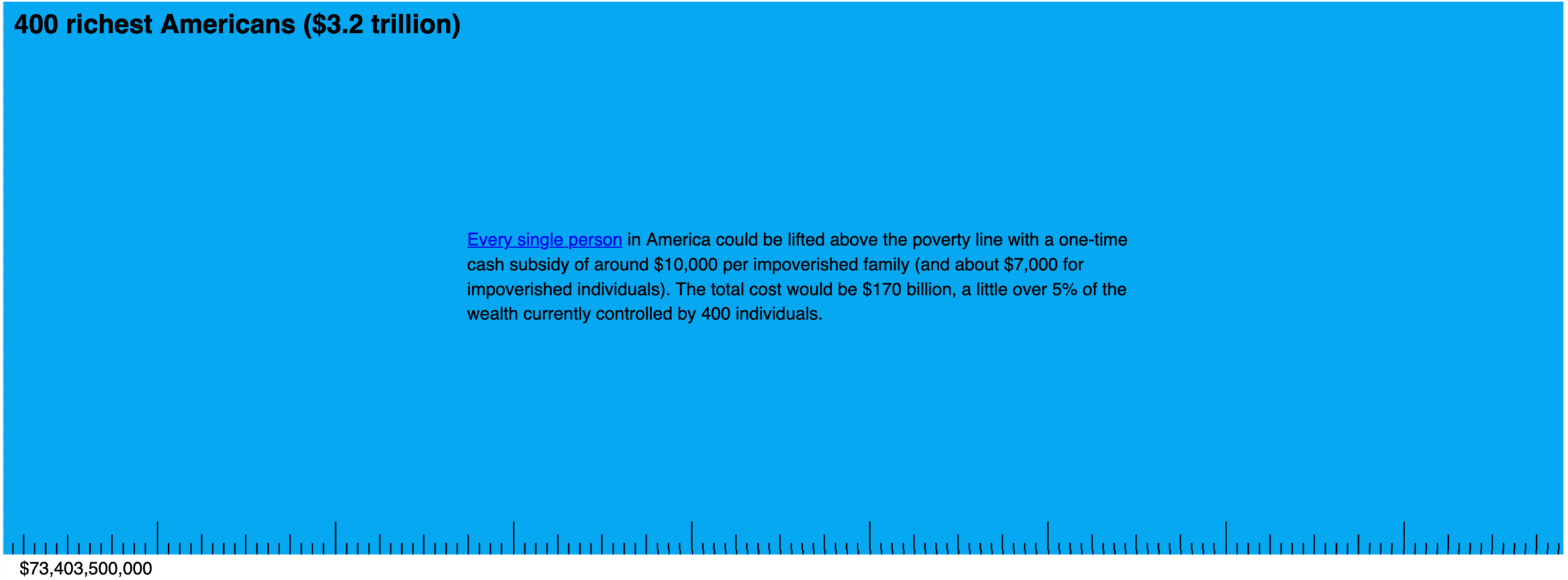
WHY DO WE WANT INTERACTIVE VISUALISATIONS?

Use 2: Monitor data

boldbi.com

WHY DO WE WANT INTERACTIVE VISUALISATIONS?

Use 3: Tell a story



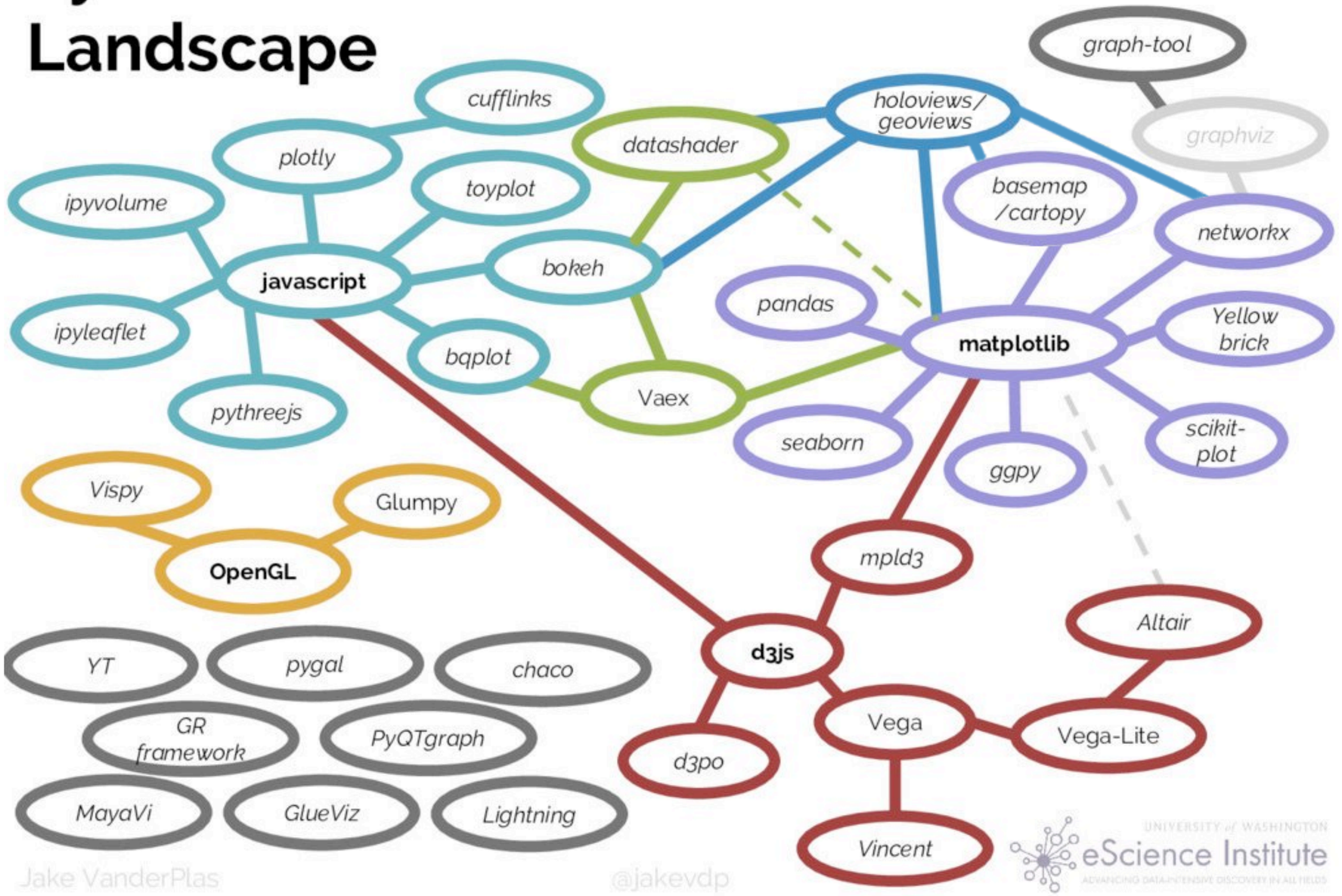
https://mkorostoff.github.io/1-pixel-wealth/

https://www.theguardian.com/uk-news/ng-interactive/2023/apr/05/revealed-royals-took-more-than-1bn-income-from-controversial-estates-king-charles-queen-duchies-cornwall-lancaster

IN R

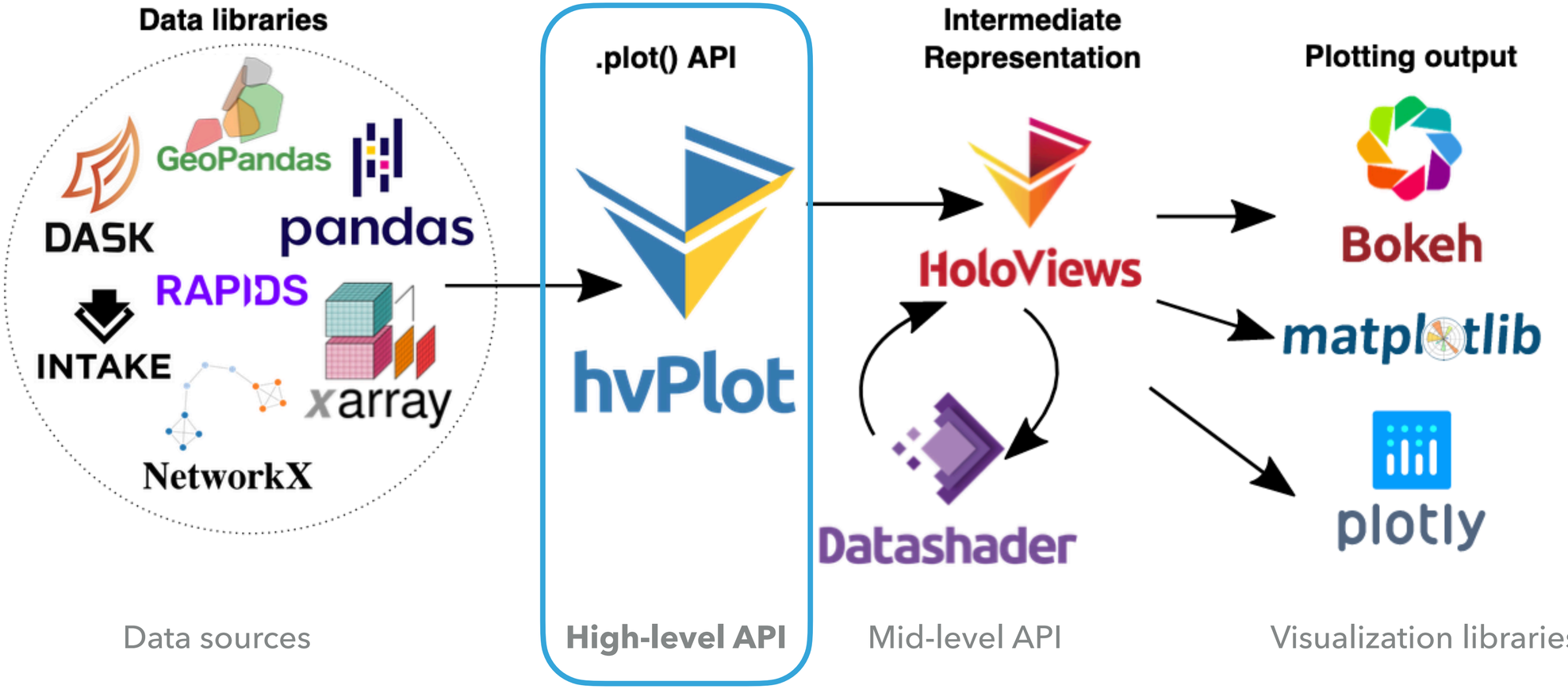
https://www.kdnuggets.com/2019/06/ten-useful-things-r.html

Python's Visualization Landscape



https://holoviz.org/tutorial/Overview.html

HOLOVIZ

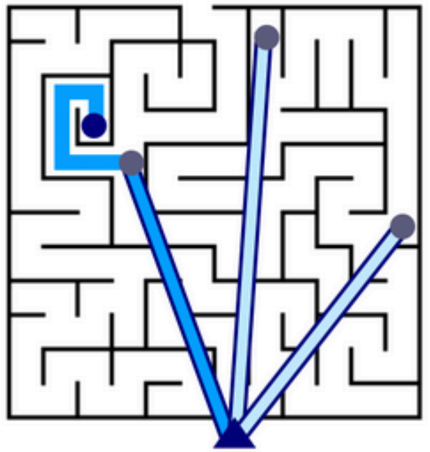

Data libraries
GeoPandas
DASK
pandas
RAPIDS
INTAKE
xarray
NetworkX
.plot() API
hvPlot
Intermediate Representation
HoloViews
Datashader
Plotting output
Bokeh
matplotlib
plotly
Data sources
High-level API
Mid-level API
Visualization libraries

Low level

✓Can precisely choose where to go

- Requires expertise to make decisions all along the way

Layered



✓Can quickly go far

✓Can precisely choose where to go

✓Only need to study where shortcut got you

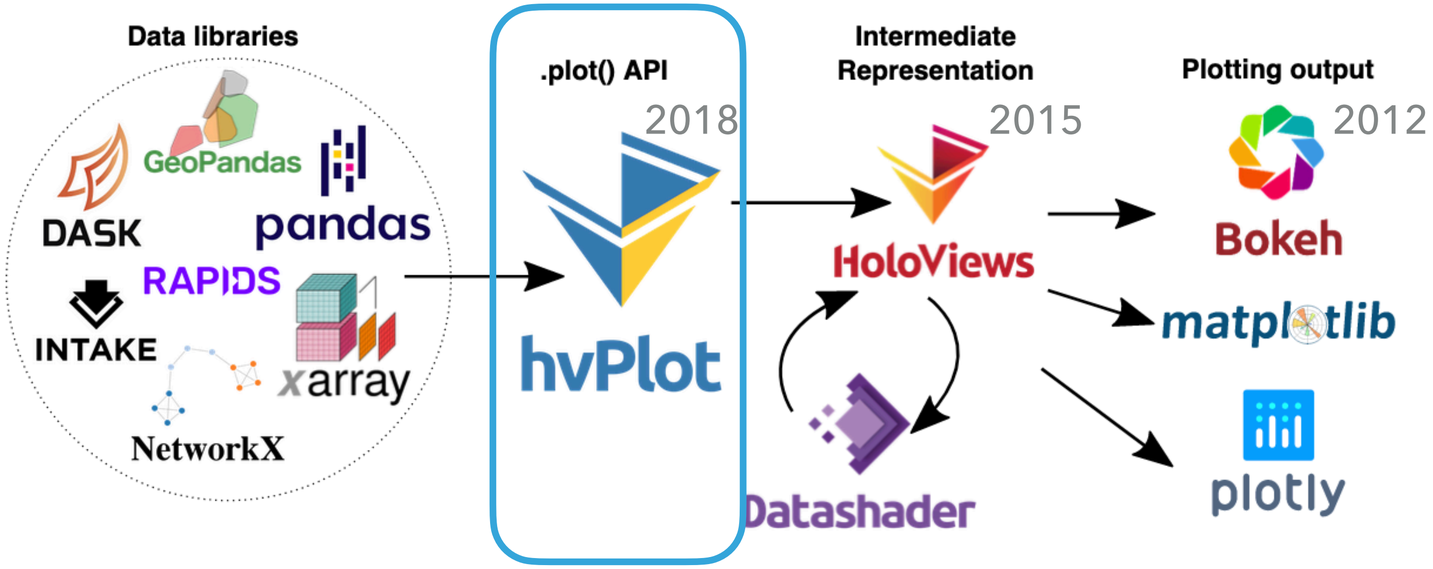
MAKING APPS

2018

Panel

Provides components, widgets, and layouts

VISUALIZATION



Advantages:

* Easy and powerful
* Uses bokeh as default (!)
* General and consistent API
* Connects very well with panel

Disadvantages:

* Fine-tuning harder than in bokeh
* New technologies
* Small user-base
    * But you can always use bokeh!

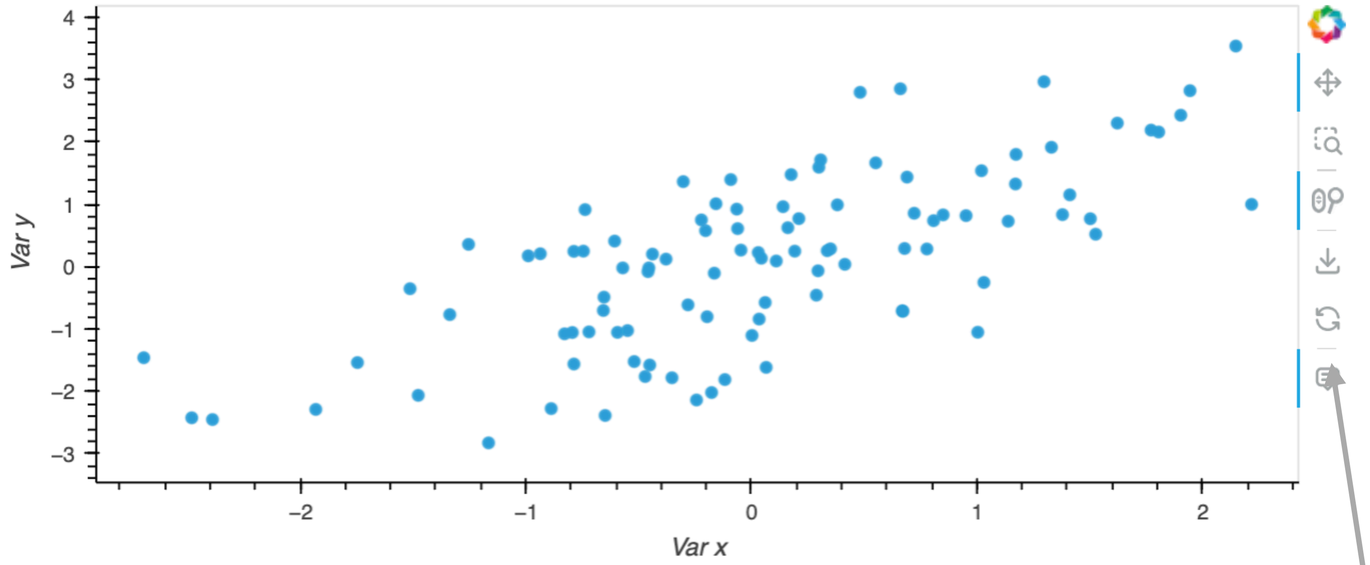
1. HVPLOT

SIMPLE PLOT

```
df = create_data(100)

# Plot
scatter = df.hvplot.scatter(x='x',
                            y='y',
                            xlabel="Var x",
                            ylabel="Var y",
                           )

# Show
scatter
```

Makes plot with some labels

x	y	class
-1.353869	-1.584364	class A
0.497119	0.546156	class B
-0.615940	-0.379600	class A
-0.142613	0.328385	class A
0.750646	0.203923	class B
-0.922876	-0.677276	class A
-1.763000	-1.978123	class A
1.263385	1.887111	class B
0.308715	1.615190	class B
0.780764	0.285989	class B



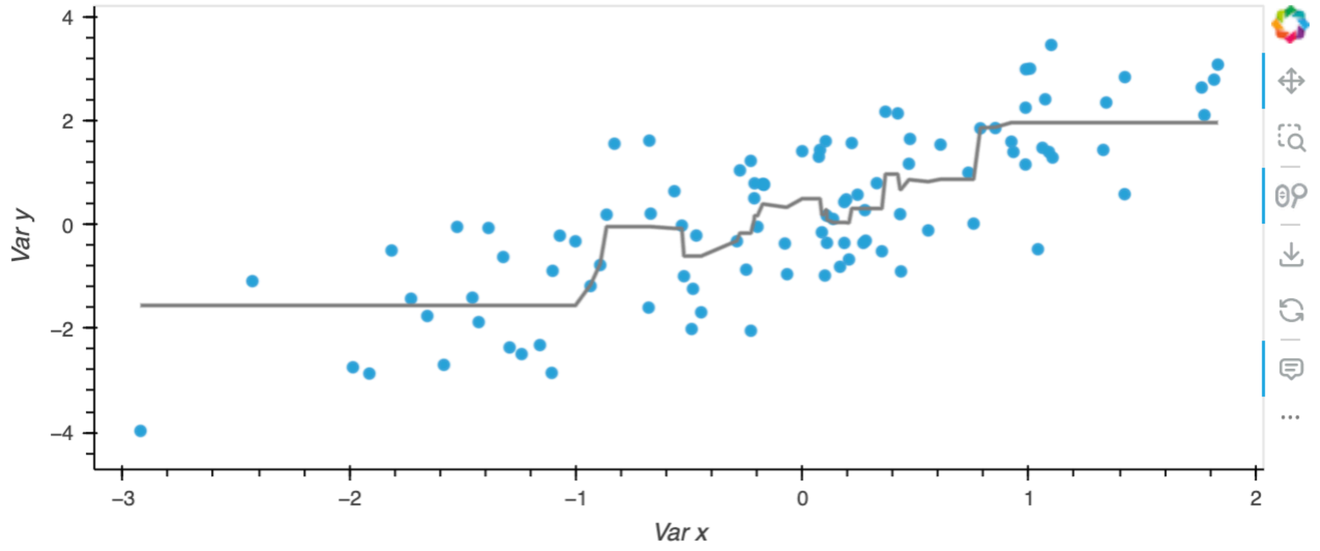
Bokeh tools

COMPOSITE PLOT

```
# Fit a fancy model on the data
fancy_model = HistGradientBoostingRegressor().fit(df[["x"]], df["y"])
df["pred"] = fancy_model.predict(df[["x"]])
# Plot the predicted values (careful, this is in-sample)
s = df.hvplot.line(x='x',
                   y='pred',
                   color="gray"
                   )

# Show
scatter * s
```

Overlay plots

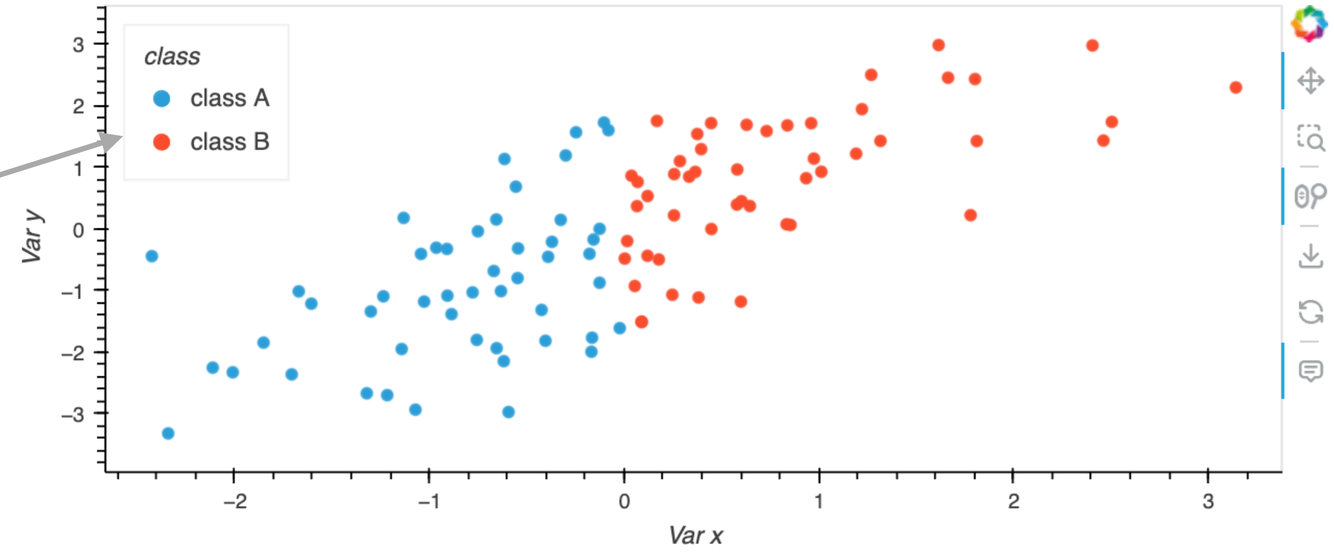
"scatter + s" would put them side by side



COLOR BY CLASS

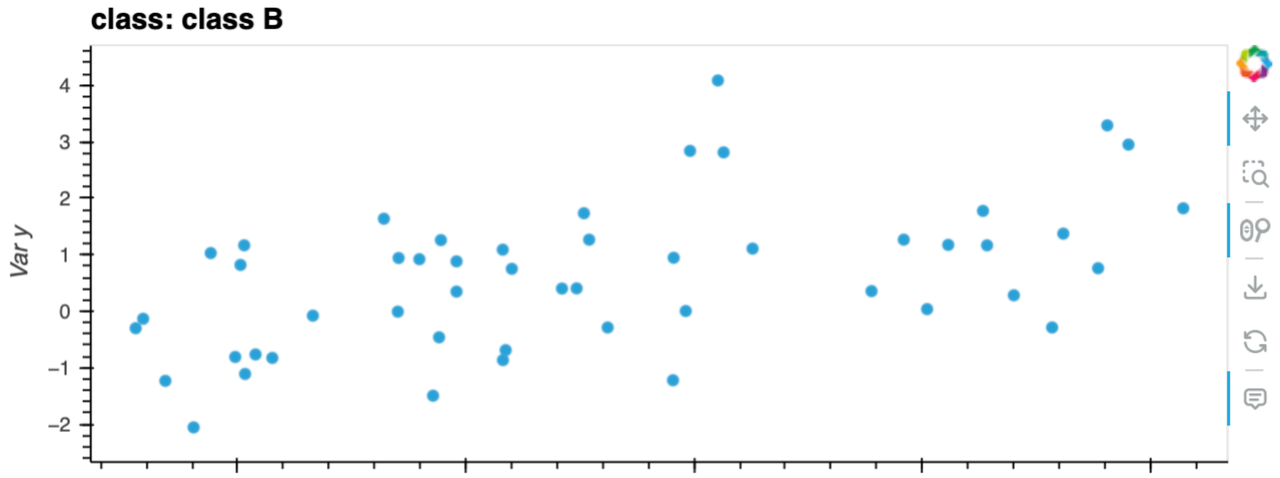
```
# Plot
scatter = df.hvplot.scatter(x='x',
                            y='y',
                            by="class",
                            xlabel="Var x",
                            ylabel="Var y",
                            legend="top_left"
                           )

# Show
scatter
```

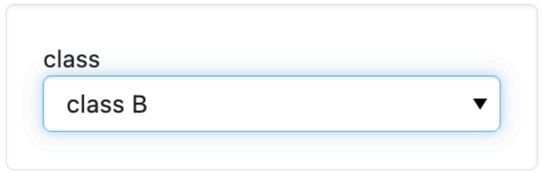
Legend interactive by default



FILTER BY CLASS

```
# Plot
scatter = df.hvplot.scatter(x='x',
                            y='y',
                            groupby="class",
                            xlabel="Var x",
                            ylabel="Var y",
                            legend="top_left",
                           )

# Show
scatter
```

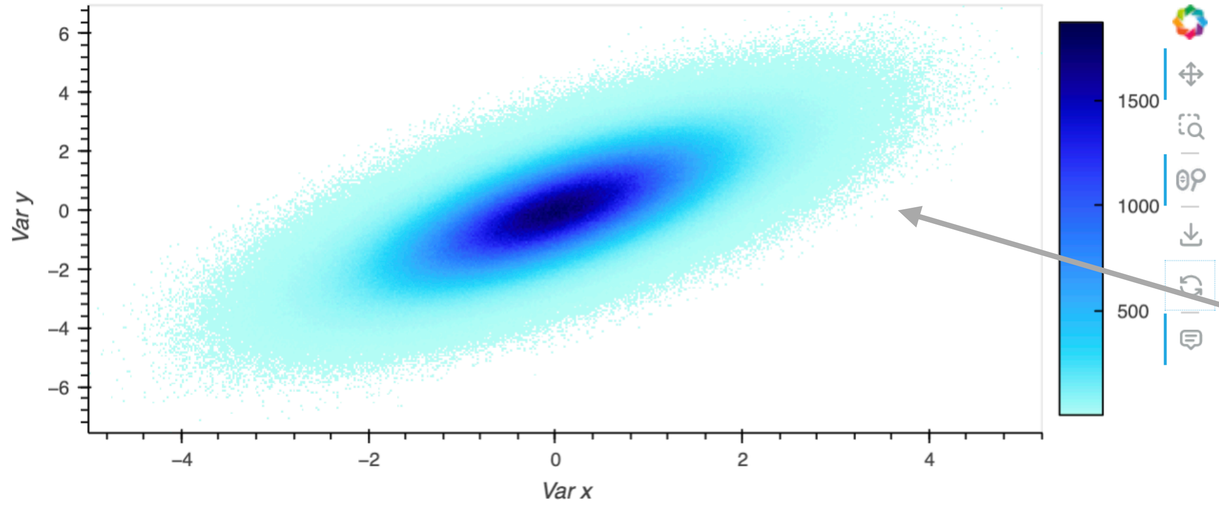




Filters by class

VISUALISE 10M POINTS

```
# Plot
scatter = df.hvplot.scatter(x='x',
                            y='y',
                            xlabel="Var x",
                            ylabel="Var y",
                            rasterize=True
                           )

# Show
scatter
```



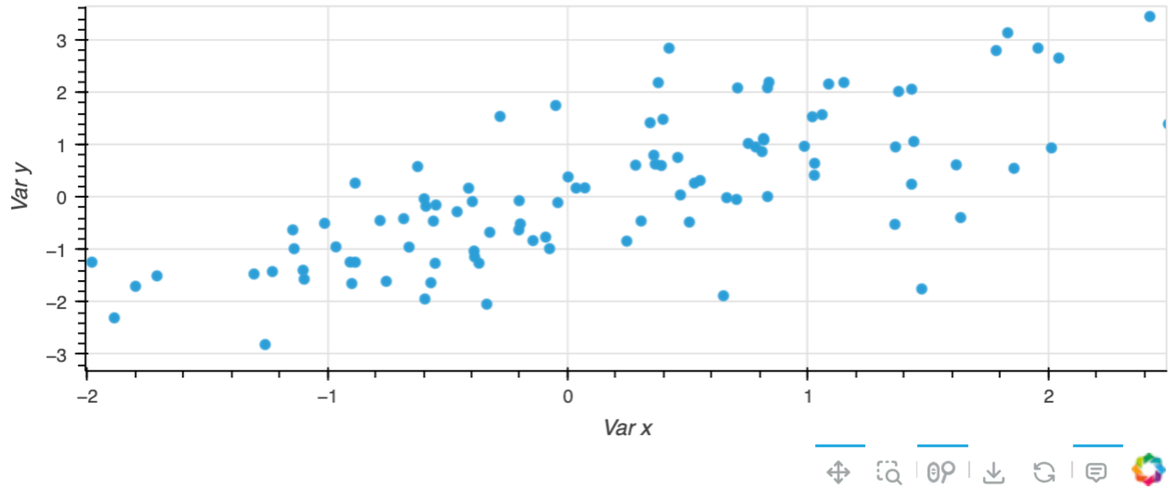
Plot updates when zoom in

BOKEH PARAMETERS

Default, work with any backend

```
# Plot
scatter = df.hvplot.scatter(x='x',
                            y='y',
                            xlabel="Var x",
                            ylabel="Var y",
                            legend="top_left",
                           )

# Show
scatter.opts(show_grid=True,
             toolbar="below")
```

Get passed to the underlying library (bokeh)

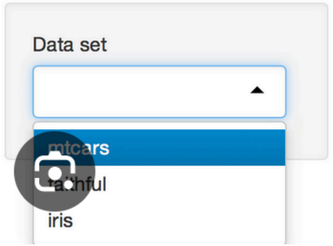


ONE OF THE MANY THINGS WHY I LOVE BOKEH: INFORMATIVE ERROR MESSAGES

```
# Plot
scatter = df.hvplot.scatter(x='x',
                            y='y',
                            xlabel="Var x",
                            ylabel="Var y",
                            legend="top_left",
                           )

# Show
scatter.opts(show_grid=True,
             toolbar="bottom")
```

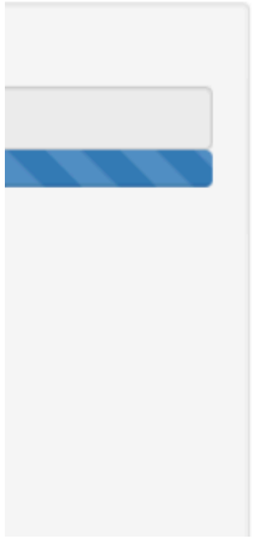
```
~/miniforge3/envs/st/lib/python3.10/site-packages/param/parameterized.py in __set__(self, obj, val)
   1199             val = self.set_hook(obj,val)
   1200
-> 1201         self._validate(val)
   1202
   1203         _old = NotImplemented

~/miniforge3/envs/st/lib/python3.10/site-packages/param/__init__.py in _validate(self, val)
   1320                     break
   1321             items = '[' + ', '.join(items) + limiter
-> 1322             raise ValueError("%s not in parameter%s's list of possible objects, "
   1323                              "valid options include %s" % (val, attrib_name, items))
   1324

ValueError: bottom not in parameter toolbar's list of possible objects, valid options include [above, below, left, right, disable, None]
```

SHINY



Error: invalid first argument

Error: invalid first argument

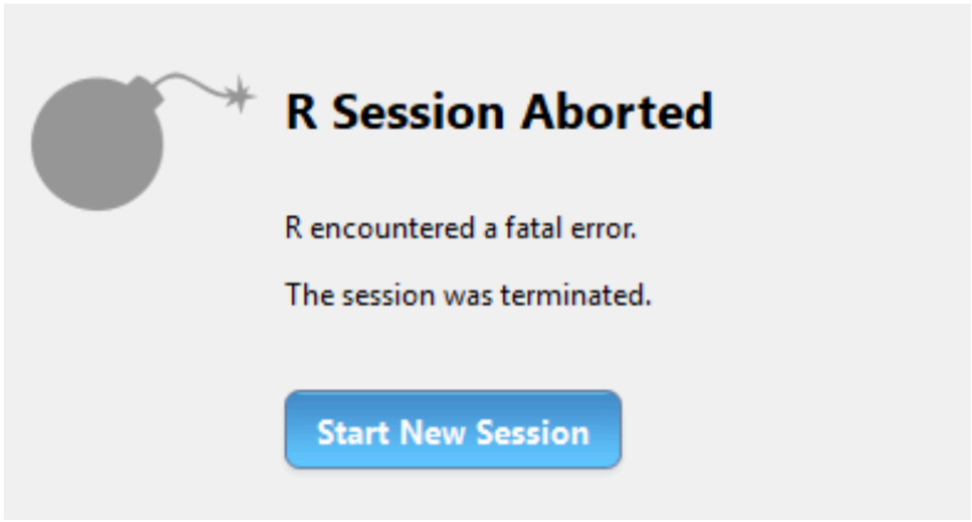


Error: An error has occurred. Check your logs or contact the app author for clarification.

An error has occurred

The application failed to start (exited with code 1).

```
── Attaching packages ─────────────────────────────────────── tidyverse 1.3.0 ──
✓ ggplot2 3.3.0     ✓ purrr   0.3.4
✓ tibble  3.0.1     ✓ dplyr   1.0.1
✓ tidyr   1.1.0     ✓ stringr 1.4.0
✓ readr   1.3.1     ✓ forcats 0.5.0
── Conflicts ────────────────────────────────────────── tidyverse_conflicts() ──
✕ dplyr::filter() masks stats::filter()
✕ dplyr::lag()    masks stats::lag()
Error in value[[3L]](cond) : app.R did not return a shiny.appobj object.
Calls: local ... tryCatch -> tryCatchList -> tryCatchOne -> <Anonymous>
Execution halted
```



2. PANEL

WHY WE NEED PANEL

Creating interactive web apps, allowing to:

- easily arrange visual components (layout)

- make them respond to user input (reactivity)

PANES

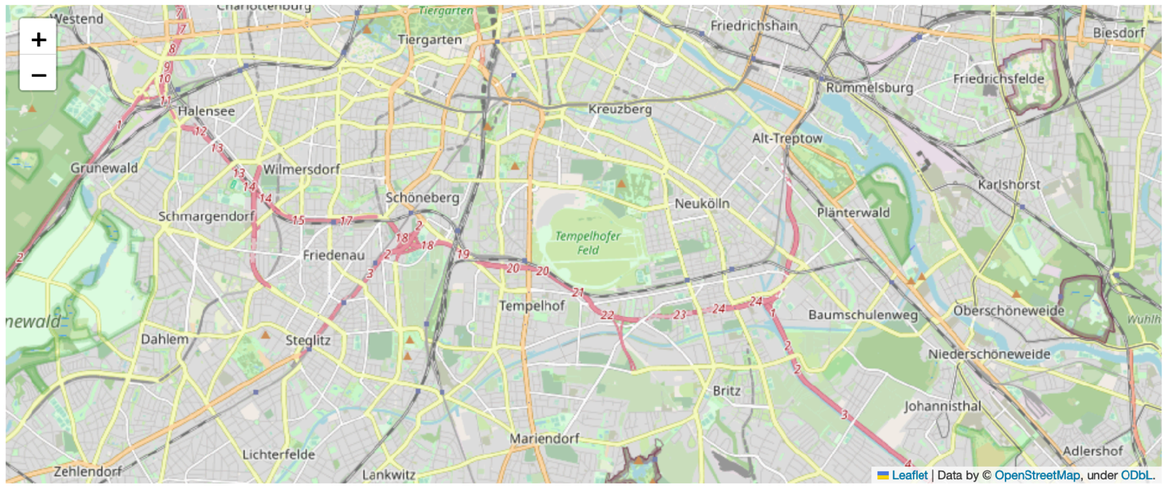
Blocks to add to your app:

* Visualizations
* Tables
* Images/Videos/PDF
* Markdown/HTML
* Alerts
* Streaming data (Perspective)

https://panel.holoviz.org/reference/index.html#panes

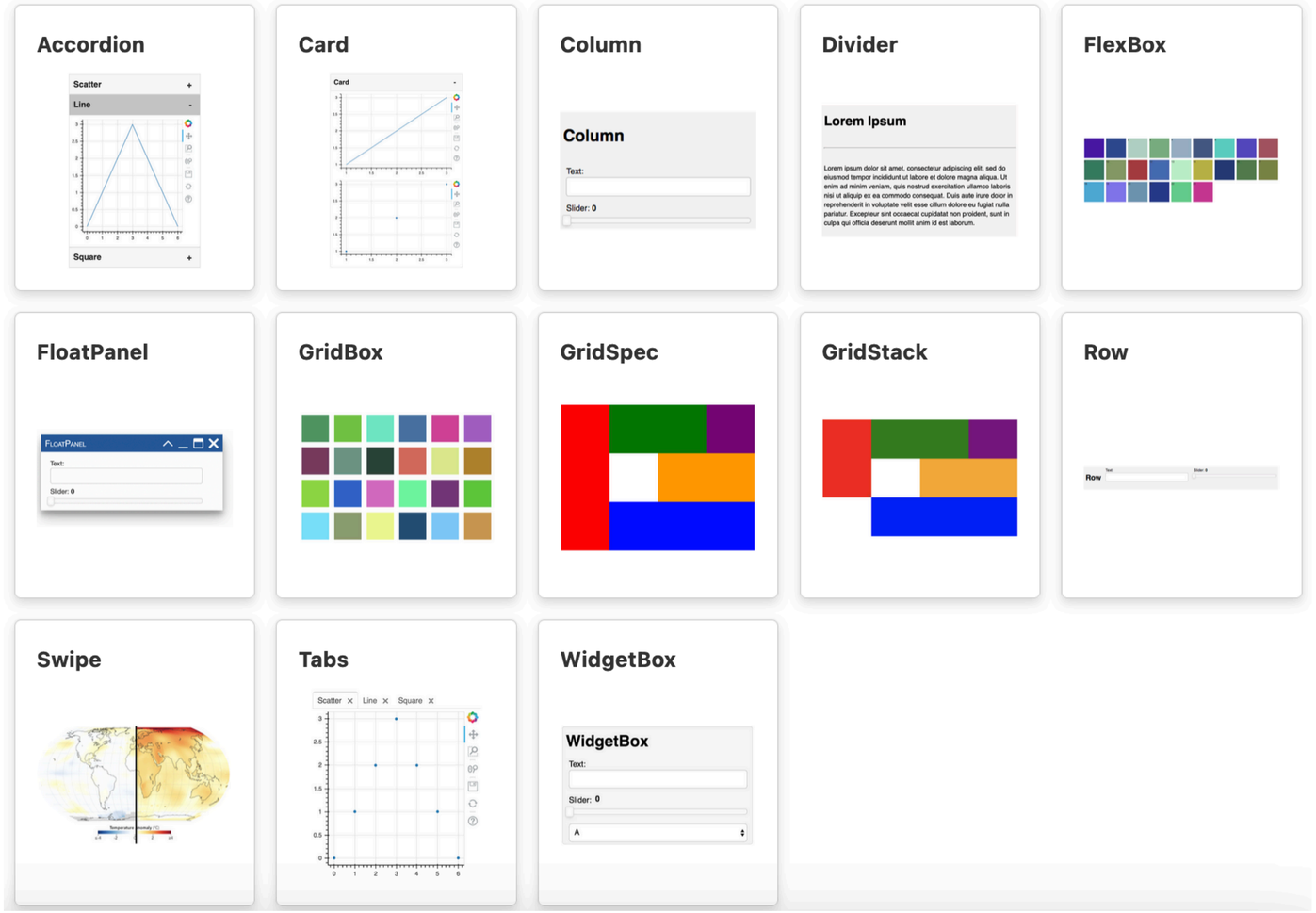
```
png_pane = pn.pane.Image('https://assets.holoviz.org/panel/samples/png_sample.png', width=400)

png_pane
```

```
m = folium.Map(location=[52.51, 13.39], zoom_start=12)

folium_pane = pn.pane.plot.Folium(m, height=400)

folium_pane
```



LAYOUT

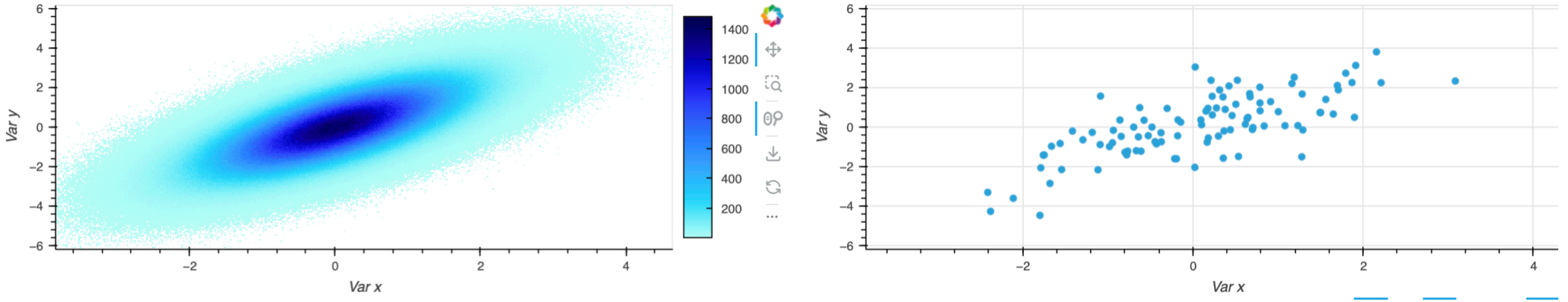
Organize your blocks



https://panel.holoviz.org/reference/index.html#layouts

2. PANEL

```
# Combine plots Linked by default!!
pn.Row(large_scatter, scatter)
```



TEMPLATES

We often don’t need full control, just want some defaults

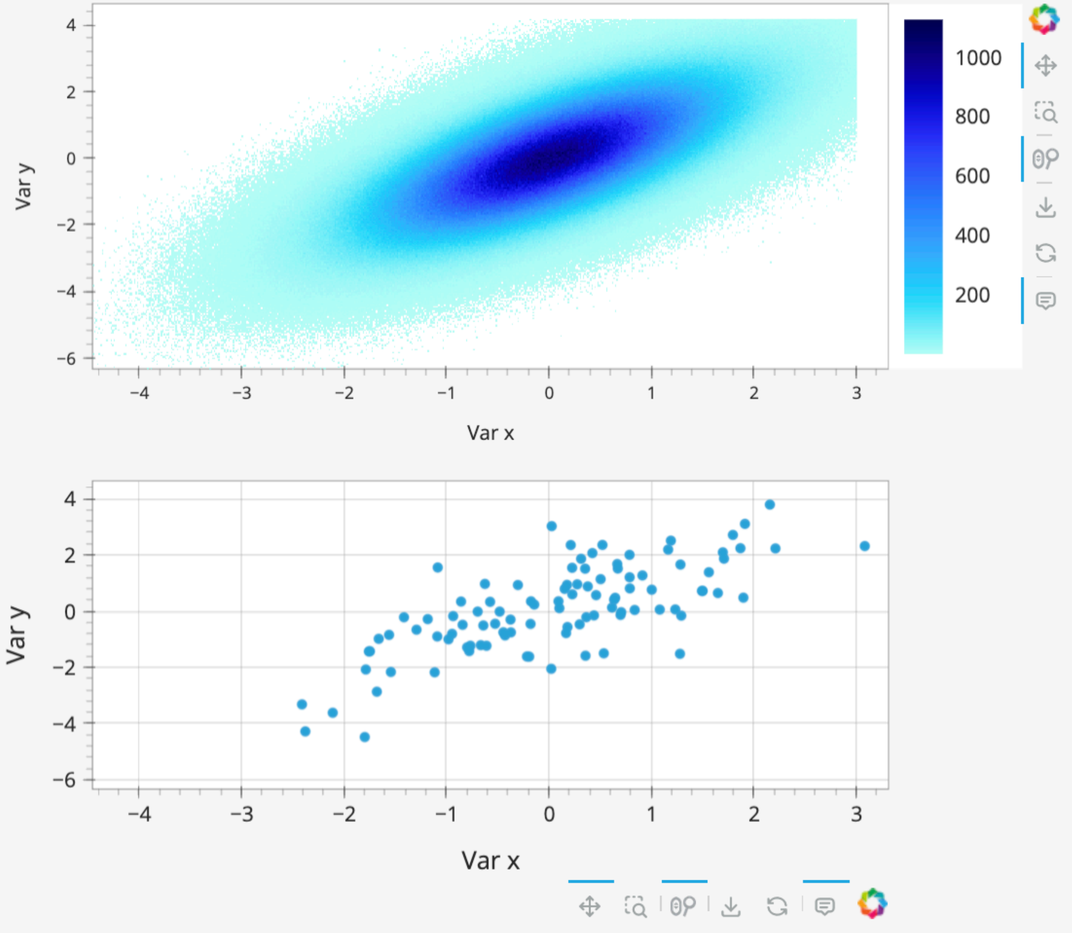
Don’t work well on notebooks (use Jupyter lab, or template.show())

https://panel.holoviz.org/reference/index.html#templates

```python
# Instantiate the template with widgets displayed in the sidebar
template = pn.template.BootstrapTemplate(
    sidebar="Here we would usually have some controls",
    main=[pn.Column(large_scatter, scatter, sizing_mode="scale_width")]
)


template.show()
```

Panel Application

Here we would usually have some controls

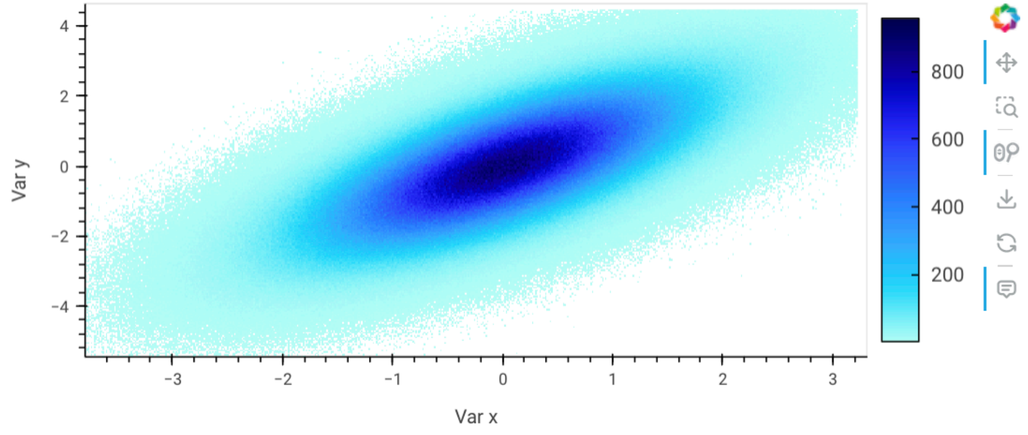


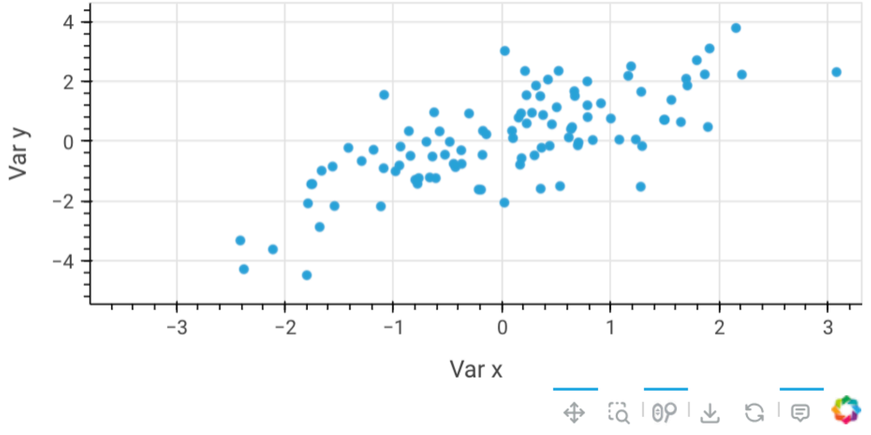
```
explanation = """
# Welcome to this cool app

This app shows my random plots
"""
explanation = pn.pane.Markdown(explanation)


# Instantiate the template with widgets displayed in the sidebar
template = pn.template.MaterialTemplate(
    title='Example template',
    sidebar=[explanation, png_pane],
    main=[pn.Column(large_scatter, scatter)],
    header=pn.pane.Str("This is the header"),
    header_background="#A01346" ,

)

template.show()
```

Example template This is the header

Welcome to this cool app

This app shows my random plots





SAVING APP/VISUALIZATIONS (I)

Interactive by default!

The data gets attached to the HTML/JS code

No server needed (for anything we've seen so far)

```
# Data gets embedded
template.save("apps/lecture_app.html")
```

EXERCISE

Build a panel app with no interactivity.

–> Check B_ex0_hvplot together

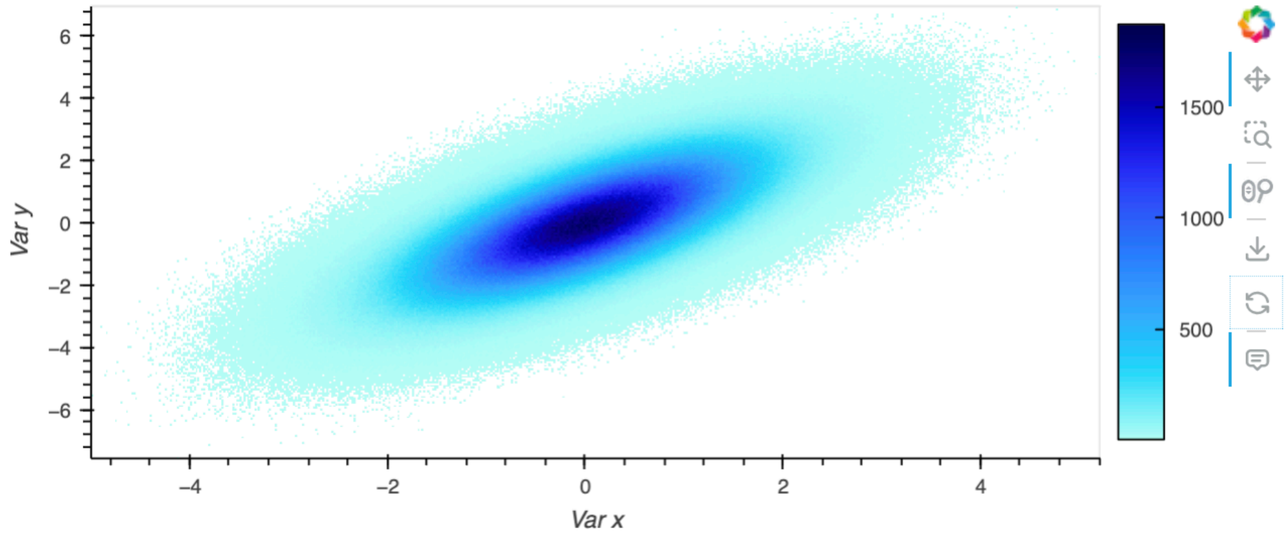
–> Work on B_ex1_intro

3. INTERACTIVITY/ REACTIVITY

INTERACTING WITH THE VISUALIZATION

Bokeh provides some interactivity, such as zooming in
Rasterize aggregates points in a smart way (using datashader)

```
# Plot
scatter = df.hvplot.scatter(x='x',
                            y='y',
                            xlabel="Var x",
                            ylabel="Var y",
                            rasterize=True
                           )

# Show
scatter
```



REACTIVITY / WIDGETS

We want to interact with the data:

* Change visualisations depending on different inputs (plot by class, select a range of values, rolling mean…)

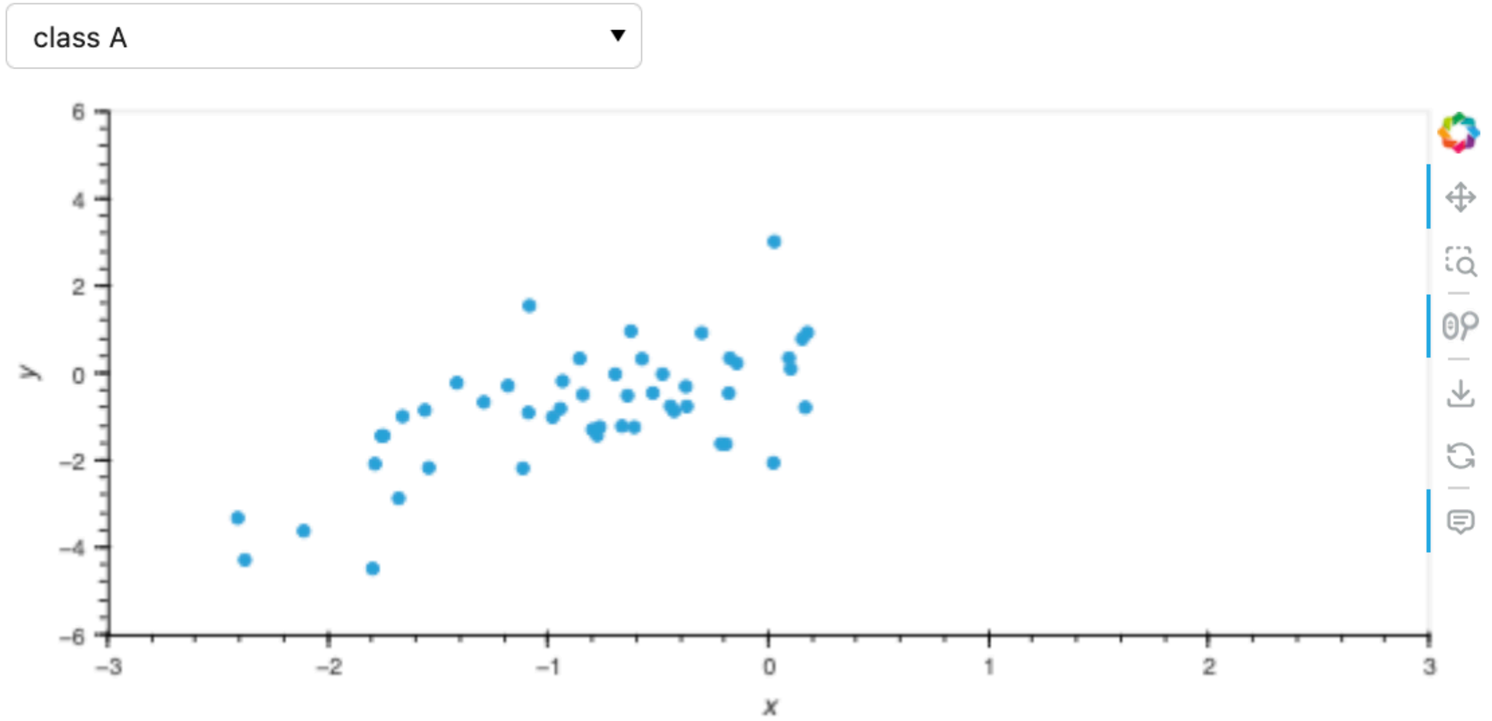
* Allowing app users to download files, record sounds, write passwords, etc

Widgets provide controls that can trigger events
(e.g. when a number is selected –> update viz)

Widget, provides value

```
w_select_class = pn.widgets.Select(options=df["class"].unique().tolist())



(dfi
    .loc[dfi["class"] == w_select_class]
    .hvplot("x",
            "y",
            kind="scatter",
            xlim=(-3,3),
            ylim=(-6,6)
           )
)
```

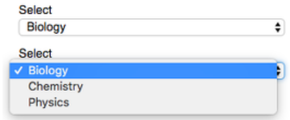
Value is used to filter data



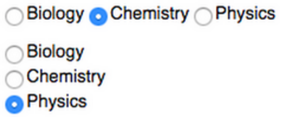
REACTIVITY / WIDGETS

https://panel.holoviz.org/reference/index.html#widgets

Select

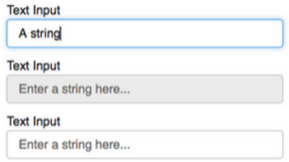


RadioBoxGroup



MultiChoice

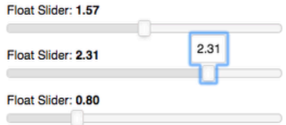
TextInput



DateRangeSlider

FloatInput

FloatSlider



Switch

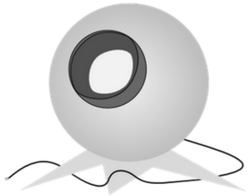
Button

FileDownload

FileInput

FileSelector

VideoStream



DiscretePlayer

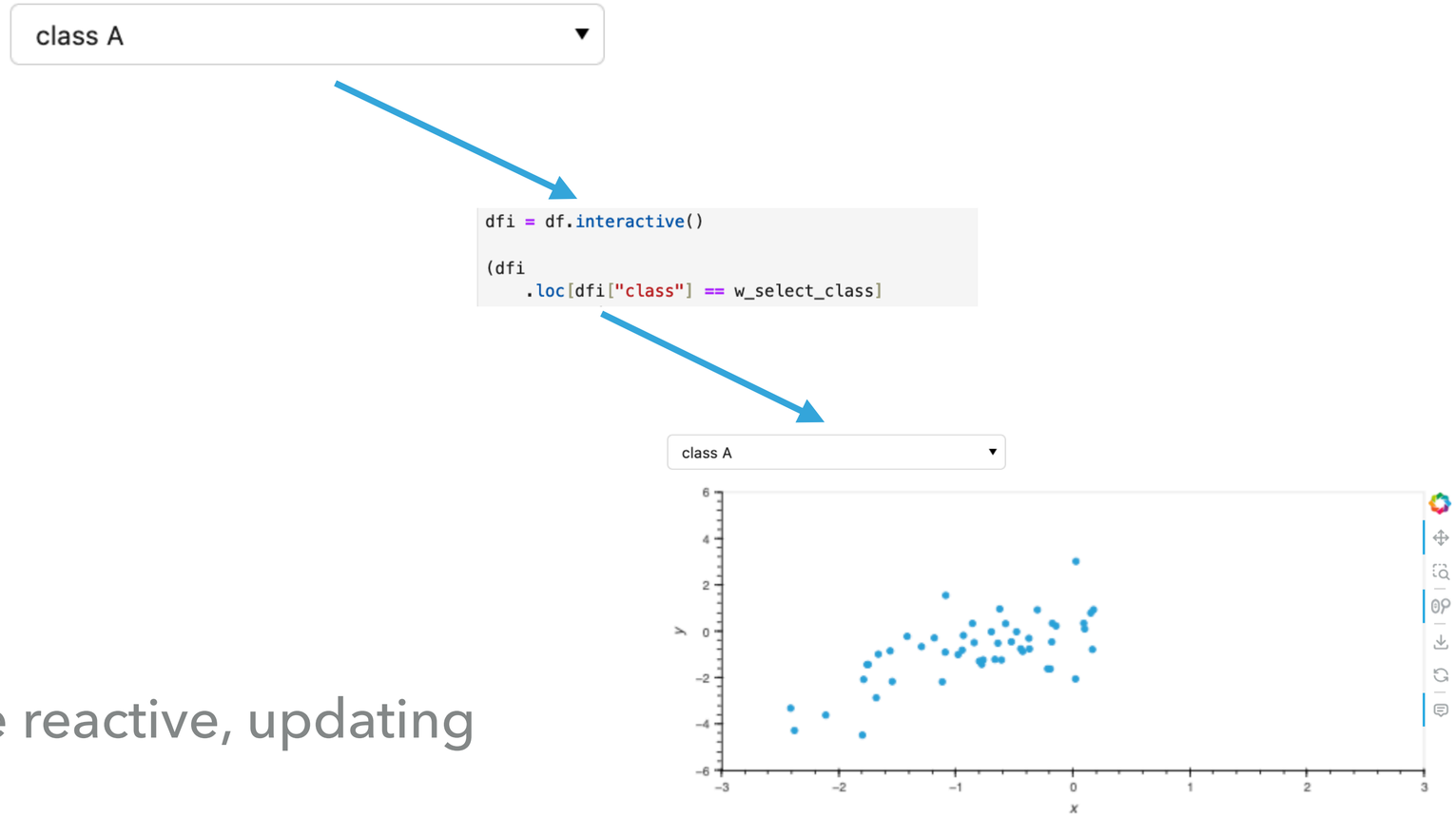
REACTIVITY

What is the value of y?

x = 1

y = x+1

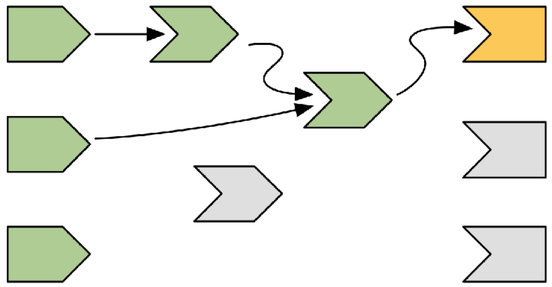
x = 5



Usually, it would be 2

In reactive programming, x and y are reactive, updating the value of x updates the value of y

This creates a graph of dependencies



Source: Mastering Shiny

REACTIVITY, SUMMARY

df.interactive()

pn.bind(function, widget)

widget.link(pane, widget_attribute="pane_attribute")

widget.param.watch(function, "widget_attribute")

REACTIVITY, WAY 1: INTERACTIVE DATA

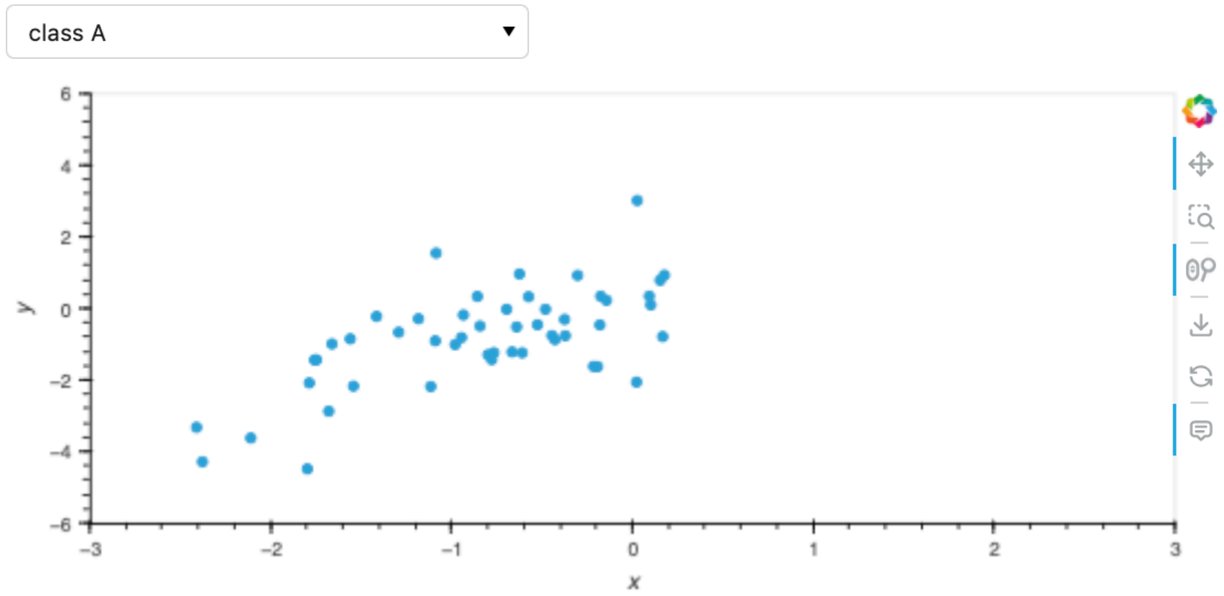
Create widget

Make your data interactive

Filter data by widget
(combinations are possible)

Plot or show data

```
w_select_class = pn.widgets.Select(options=df["class"].unique().tolist())

# Interactive data
dfi = df.interactive()

(dfi
    .loc[dfi["class"] == w_select_class]
    .hvplot("x",
            "y",
            kind="scatter",
            xlim=(-3,3),
            ylim=(-6,6)
           )
)
```



Main disadvantage: introduced in 2020

REACTIVITY, WAY 2: BINDING WIDGETS AND FUNCTIONS

Create a function that affects an element of the layout, depending on the value of a widget.

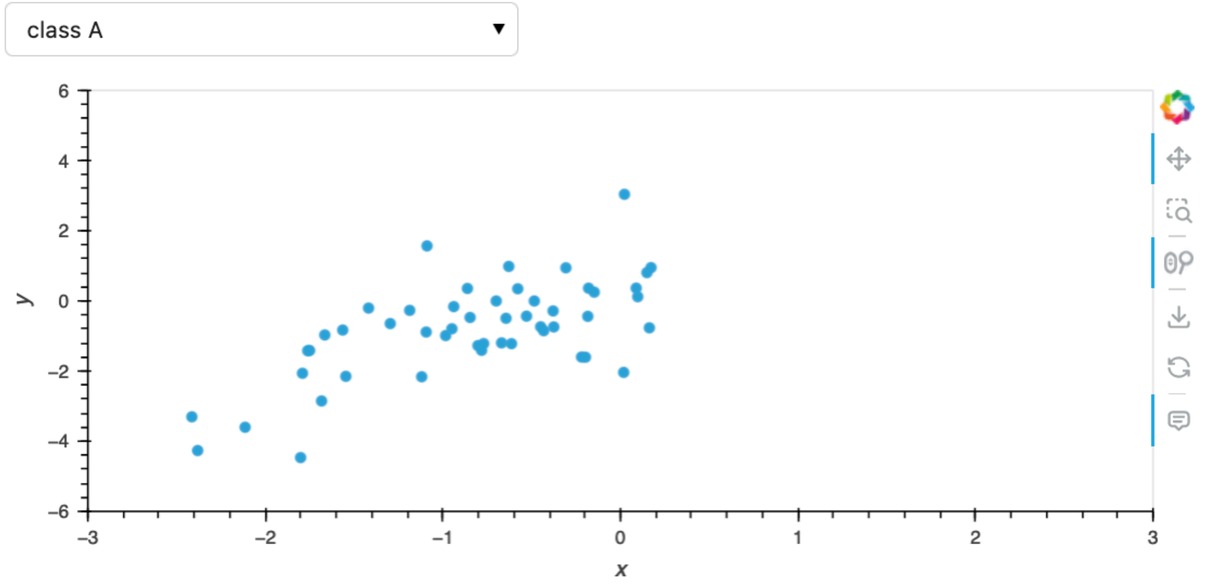
Bind the function and the widget:

pn.bind(*function*, arg_function=widget)

Advantage: More flexible/powerful

Not restricted to data operations!

```
w_select_class = pn.widgets.Select(options=df["class"].unique().tolist())

def interactive_plot(class_subset):
    return (
        df
        .loc[df["class"] == class_subset]
        .hvplot("x",
                "y",
                kind="scatter",
                xlim=(-3,3),
                ylim=(-6,6)
               )
    )

interactive_plot2 = pn.bind(interactive_plot, class_subset=w_select_class)

pn.Column(w_select_class, interactive_plot2)
```



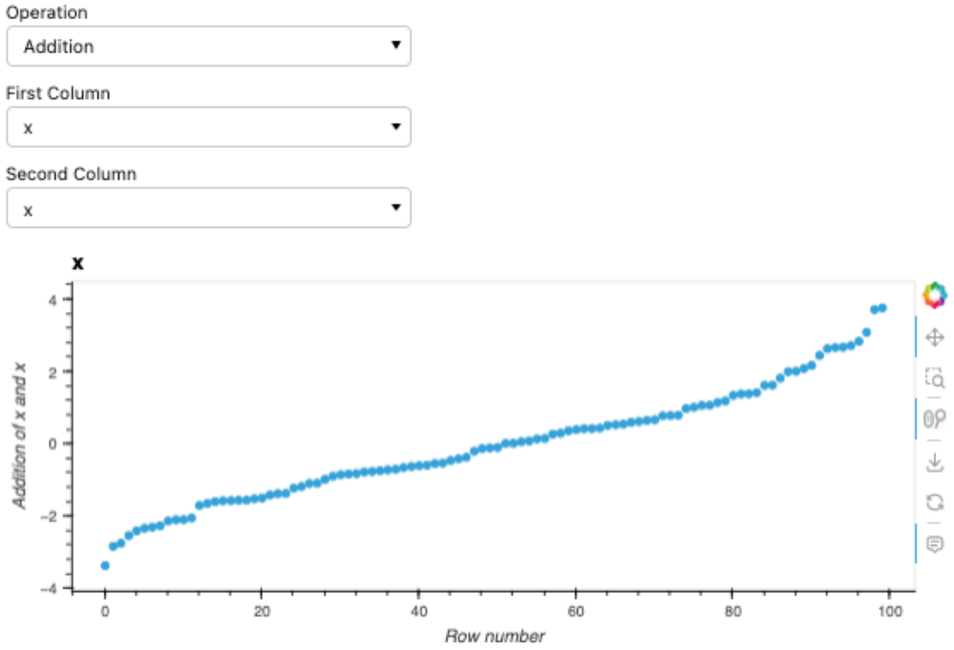
3. INTERACTIVITY/REACTIVITY

Function creates non-trivial data transformation

Bind the function and several widgets:

pn.bind(*function*, arg_function=widget)

```python
# Widgets
operation_selector = pn.widgets.Select(name="Operation", options=['Addition', 'Subtraction', 'Multiplication', 'Division'])
column_selector1 = pn.widgets.Select(name="First Column", options=["x", "y"])
column_selector2 = pn.widgets.Select(name="Second Column", options=["x", "y"])

def plot_data(operation, col1, col2):
    if operation == 'Addition':
        result = df[col1] + df[col2]
    elif operation == 'Subtraction':
        result = df[col1] - df[col2]
    elif operation == 'Multiplication':
        result = df[col1] * df[col2]
    elif operation == 'Division':
        result = data[col1] / data[col2]
    return result.hvplot(kind="scatter", xlabel="Row number", ylabel=f"{operation} of {col1} and {col2}")

# Bind the function to widget values
interactive_plot = pn.bind(plot_data, operation=operation_selector, col1=column_selector1, col2=column_selector2)

# Display
dashboard = pn.Column(operation_selector, column_selector1, column_selector2, interactive_plot)
dashboard.servable()
```



REACTIVITY, WAY 3: LINKING WIDGETS

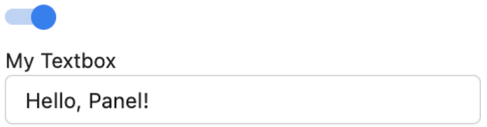
.link() links a widget to a pane/widget, making them have exactly the same value

Create widgets

Link the value of the toggle to the attribute “visible” of the textbook

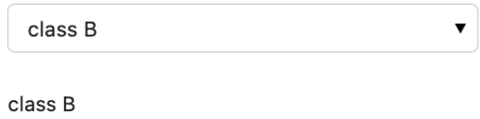
If toggle becomes “False” (i.e. turned off) –> the argument visible of the textbox is set to False

```
# Linking two widgets

toggle = pn.widgets.Switch(name='Show Textbox', value=True)
textbox = pn.widgets.TextInput(name='My Textbox', value='Hello, Panel!')

toggle.link(textbox, value='visible')

pn.Column(toggle, textbox)
```



Link the value of w_select_class to the attribute “object” of the markdown

```
# Linking a pane to a widgget
w_select_class = pn.widgets.Select(options=df["class"].unique().tolist())
selections = pn.pane.Markdown(object=f'Select a class')


w_select_class.link(selections, value="object")

pn.Column(w_select_class, selections)
```



REACTIVITY, WAY 4: WATCHING WIDGETS

All Panel objects store their main component on their *object* parameter.

Buttons have an .on_click() function

```
w_button = pn.widgets.Button(name='Click me', button_type='primary')
selections = pn.pane.Markdown(object='You have not clicked the button')

def print_selected(event):
    selections.object = f"You have clicked the button {event.new} times"


w_button.on_click(print_selected)

pn.Column(w_button, selections)
```

REACTIVITY, WAY 4: WATCHING WIDGETS

.watch() watches for changes in parameter and runs a function

works through events (event.new, event.old, event.name)

Watch the Select widget, and on change of its *value* run the function

```
# Linking a pane to a widgget
w_select_class = pn.widgets.Select(options=df["class"].unique().tolist())
selections = pn.pane.Markdown(object=f'Select a class')

def selected_class(event):
    selections.object = f"The selected class is {event.new}"

w_select_class.param.watch(selected_class, "value")

pn.Column(w_select_class, selections)
```

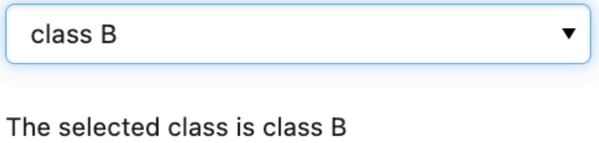
The selected class is class B

REACTIVITY, WAY 4: WATCHING WIDGETS

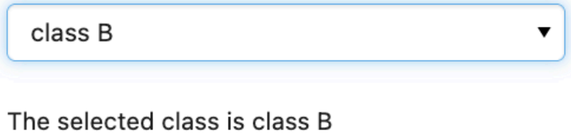
.watch() watches for changes in parameter and runs a function

The same code using pn.bind

```
# Linking a pane to a widgget
w_select_class = pn.widgets.Select(options=df["class"].unique().tolist())
selections = pn.pane.Markdown(object=f'Select a class')

def selected_class(event):
    selections.object = f"The selected class is {event.new}"

w_select_class.param.watch(selected_class, "value")

pn.Column(w_select_class, selections)
```




```
# You can also do it with pn.bind
w_select_class = pn.widgets.Select(options=df["class"].unique().tolist())

# Define a function that returns the Markdown text based on the selected class
def update_selection(selected):
    return f"The selected class is {selected}"

# Bind the function to the widget value
selections = pn.pane.Markdown(object=pn.bind(update_selection, w_select_class))

pn.Column(w_select_class, selections)
```



REACTIVITY, SUMMARY

df.interactive()

Directly links DataFrames to widgets
Example: Filtering data based on widgets

pn.bind(function, widget)

Binding functions to widgets
Example: Doing more complex operations depending on the value of the widget

widget.link(pane, widget_attribute="pane_attribute")

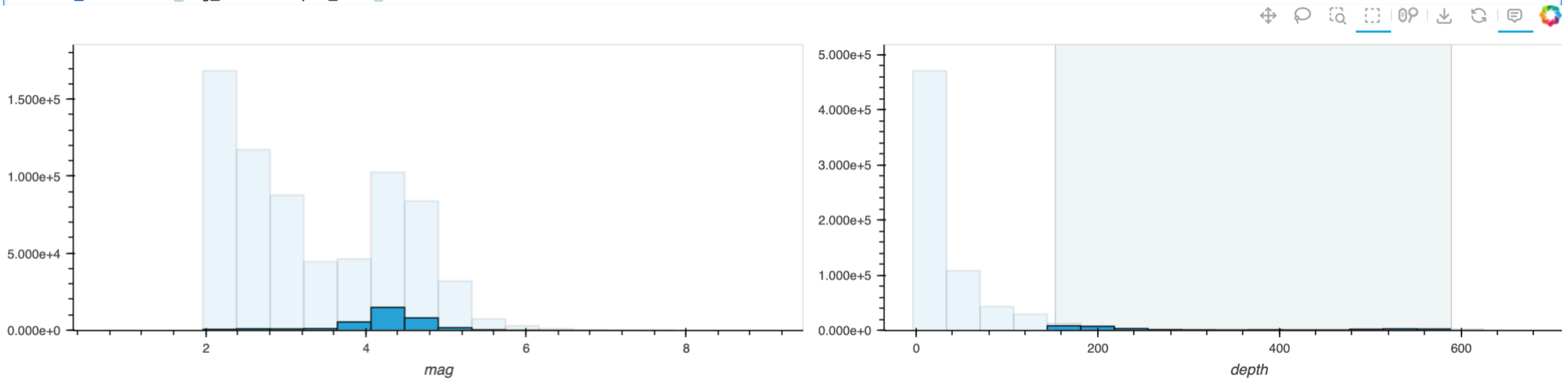
Create a direct link between widget properties
Example: Area becomes visible is toggle is switched on

widget.param.watch(function, "widget_attribute")

Setting up callbacks (functions) for custom logic
Example: Running a series of custom operations when a value changes

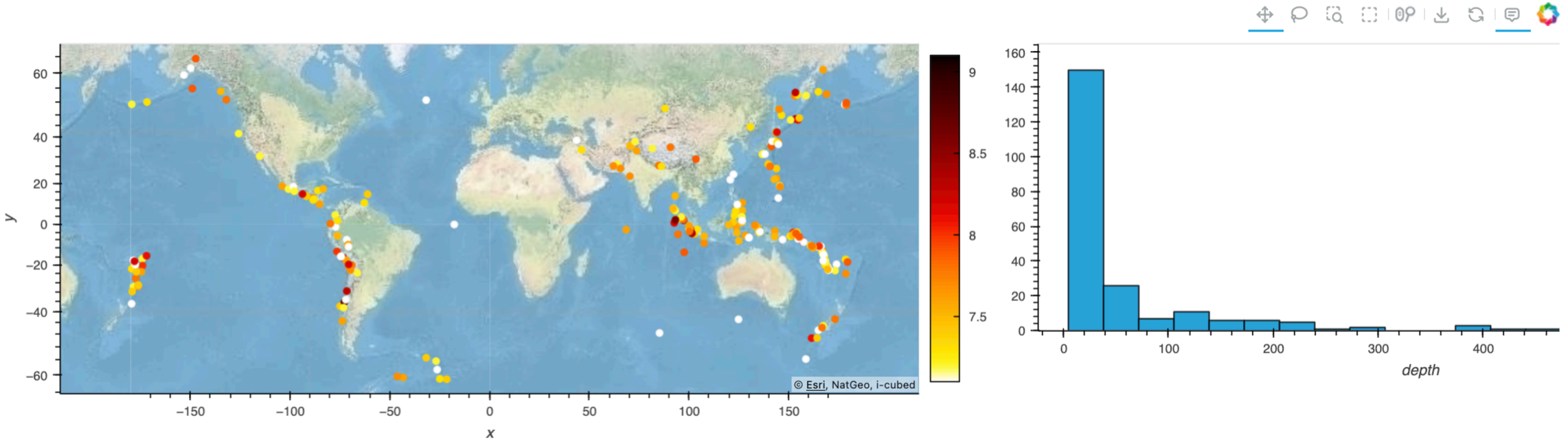
LINKING PLOTS (BRUSHING)

```
mag_hist = df.hvplot(
    y='mag', kind='hist', min_height=250)

depth_hist = df.hvplot(
        y='depth', kind='hist', min_height=250)

# Linked brushing
import holoviews as hv
hv.link_selections(mag_hist + depth_hist)
```



LINKING PLOTS (BRUSHING)

```
df_sev = df.loc[df["mag"]>7]
geo = df_sev.hvplot.points('longitude', 'latitude', geo=True, color='mag', cmap="fire_r",
                           tiles='EsriUSATopo', min_height=250)
hist = df_sev.hvplot.hist('depth', min_height=250)

hv.link_selections(geo + hist)
```

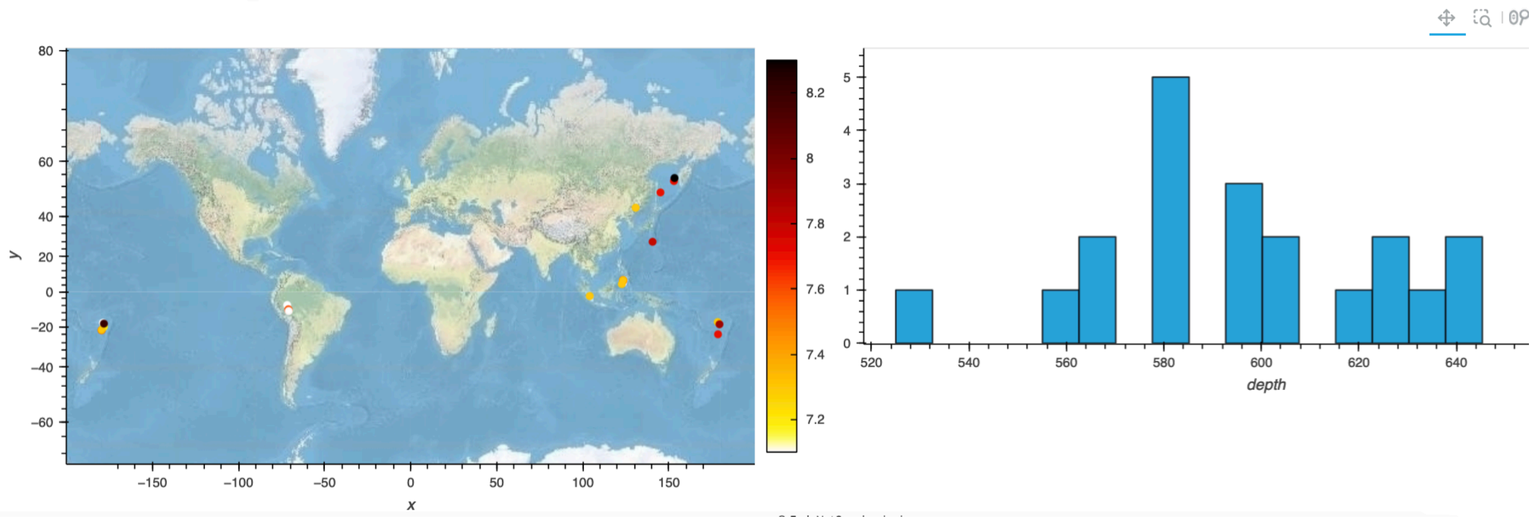


LINKING PLOTS (INTERACTIVE DATA)

```
# Earthquake data
df = pd.read_parquet('data/earthquakes.parq', 'fastparquet').interactive()

# Two widgets
mag_select = pn.widgets.FloatSlider(name = "Minimum magnitude", end=9.2, value=7, step=0.1)
depth_select = pn.widgets.FloatSlider(name = "Minimum depth", start=-10, end=750, value=500, step=10)

df_subset = df.loc[(df["mag"] > mag_select)  &
                   (df["depth"] > depth_select)]


geo = df_subset.hvplot.points('longitude', 'latitude', geo=True, color='mag', cmap="fire_r",
                         tiles='EsriUSATopo', responsive=True,  height=400, width=700).opts(toolbar="below")
hist = df_subset.hvplot.hist(y='depth', min_height=250)

pn.panel(geo + hist)
```

Minimum magnitude: **7**

Minimum depth: **500**



EXERCISE

Play with interactivity

–> Check section 3: B_z_lecture_examples.ipynb

–> Work on: B_ex2_reactivity

4 MAIN ADVANTAGES OF PYTHON/PANEL/HVPLOT/BOKEH

1. Easy apps/viz do not need :
    * a complicated setup
    * a server
2. Iterative app building, testing each part independently
3. Informative error messages (bokeh <3)
4. Apps can run on the browser (privacy, easiness)

4. EXPORTING APPS/ SERVERS

Apps with widgets may require a server for interactivity

But if there are not many options you can embed all possible states of the visualization

```
#Export the app
layout.save('apps/simple_app_template.html', embed=True)
```

Apps running python code require a server to run.

Options to run them:

- Locally (e.g. on juypter notebook/lab)
- Locally (*panel serve your_app.py*)
- On a server (e.g. AWS)
- **Using the browser as a server**

```
##Convert to WASM app

panel convert bokeh_app.py --to pyodide-worker --out ./app --pwa

#Launch server to test locally (or upload to GitHub pages)

#python3 -m http.server
```

Upload your site to Github Pages (username.github.io/repository)

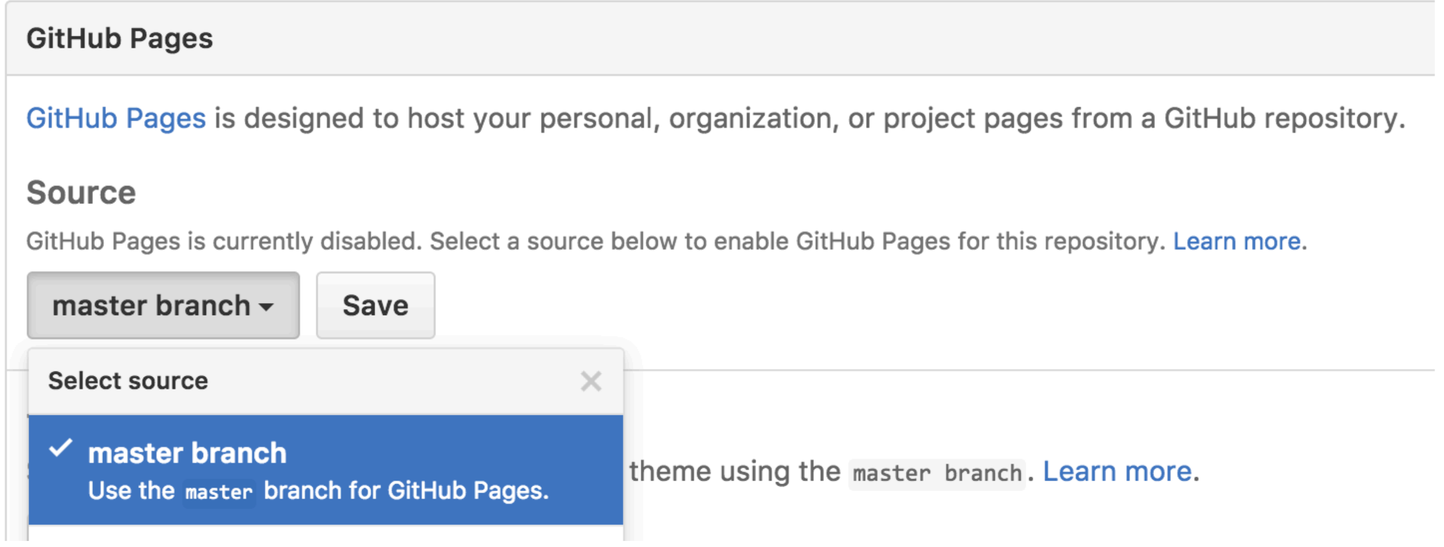
1. Create a personal GitHub page: https://pages.github.com/
2. Create a new repository
3. Upload the files created after *panel convert bokeh_app.py --to pyodide-worker --out ./app --pwa*

(the main file should be index.html)

4. Do this step

Click on the Settings tab and scroll down to the GitHub Pages section.

Then select the **main branch** source and click on the **Save** button.



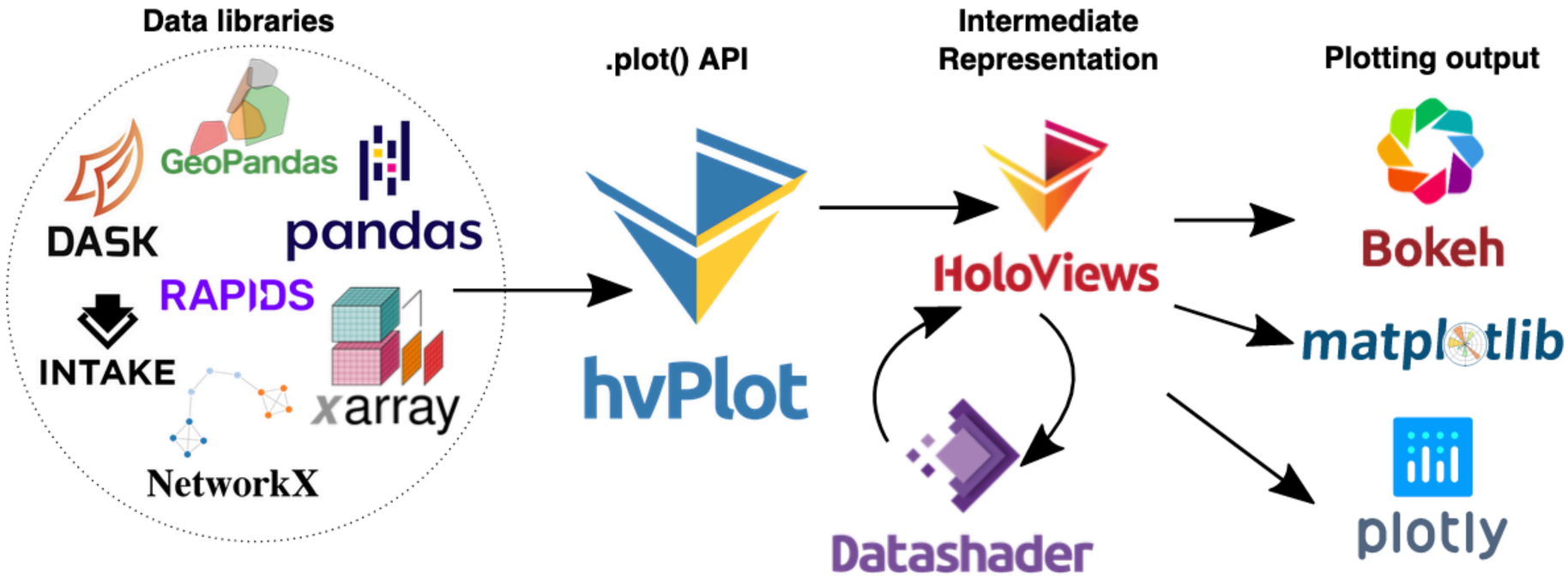
WHERE TO GO FROM HERE

Documentation of hvPlot

Custom visualizations? –> holoViews

More on apps/dashboards? –> panel

Use apps to label/collect data: https://holoviews.org/user_guide/Annotators.html



EXAMPLES

https://javier.science/panel_network/

https://javier.science/panel_bias_variance/

https://javier.science/panel_latent_class_analysis/

http://javier.science/panel_sicss_results/

EXERCISE

Work on your own app