

# svd

August 17, 2022

```
[1]: import os

import numpy as np
import pandas as pd

import matplotlib.pyplot as plt
import plotly.express as px
import plotly.graph_objects as go

[2]: import plotly.io as pio
pio.renderers.default = "plotly_mimetype+notebook+vscode+pdf"

[3]: def create_folder(folder_name):
    if not os.path.exists(folder_name):
        print(f'Creating folder {folder_name}')
        os.mkdir(folder_name)

    # to always have the newest plot versions, delete file before creating new one
    def remove_file_if_exists(file_path):
        if os.path.exists(file_path):
            os.remove(file_path)

    create_folder('data/')
    create_folder('data/svd')

[4]: # keep only needed data
def truncate_df(df, columns_to_keep, years=None, months=None, hours=None):
    # modify timestamp column
    df['date_time'] = pd.to_datetime(df['date_time'], format='%Y-%m-%d %H:%M:%S')

    # build prefix str
    prefix_str = 'columns-' + '_'.join(columns_to_keep)
    columns_to_keep = ['date_time'] + columns_to_keep + ['city']
    df = df[columns_to_keep]

    if years:
        df = df[df['date_time'].dt.year.isin(years)]
```

```

prefix_str += '-years-' + '_'.join(map(str, years))

if months:
    df = df[df['date_time'].dt.month.isin(months)]
    prefix_str += '-months-' + '_'.join(map(str, months))

if hours:
    df = df[df['date_time'].dt.hour.isin(hours)]
    prefix_str += '-hours-' + '_'.join(map(str, hours))

prefix_str = prefix_str.replace(' ', '')
return df, prefix_str

```

## 0.1 Prepare Data for SVD Analysis

[5]: # function to create csv file used for analysis

```

def create_svd_df(df, column_value, outstring):
    OUTPUT_FILENAME = f'data/svd/data_svd_{outstring}.csv'

    unique_towns = sorted(list(df['city'].unique()))

    new_index = pd.to_datetime(df['date_time'], format='%Y-%m-%d %H:%M:%S').
    ↪unique()
    data = np.array(df[column_value])
    data = data.reshape(len(new_index), len(unique_towns))

    ret_df = pd.DataFrame(
        data=data,
        columns=unique_towns,
        index=new_index,
        dtype=float
    )
    ret_df.to_csv(OUTPUT_FILENAME)

```

[6]: # svd global variables and creating dirs

```

SVD_FOLDER_PATH = 'svd_plots'
create_folder(SVD_FOLDER_PATH)

FULL_DATA_FILENAME = 'data/data.csv.gz'

COLUMNS_TO_KEEP = ['tempC']
df_data = pd.read_csv(FULL_DATA_FILENAME, compression='gzip')

df_data, PREFIX_STR = truncate_df(
    df=df_data.copy(),
    columns_to_keep=COLUMNS_TO_KEEP,
)

```

```

    months=[6,7,8,9],
)

SVD_FOLDER_PATH = f'{SVD_FOLDER_PATH}/{PREFIX_STR}'
create_folder(SVD_FOLDER_PATH)

# create reconstruction dir
# SVD_RECONSTRUCTION_FOLDER_PATH = f'{SVD_FOLDER_PATH}/reconstruction'
# create_folder(SVD_RECONSTRUCTION_FOLDER_PATH)

```

Creating folder svd\_plots/columns-tempC-months-6\_7\_8\_9

```
[7]: GEOLOCATION_FILENAME = 'data/geo_position.csv'
df_geolocation = pd.read_csv(GEOLOCATION_FILENAME).sort_values(by='CITY')
unique_towns = sorted(list(df_geolocation['CITY'].unique())) # get unique ↴
↪ names of towns ordered by name

SVD_DATA_FILENAME = f'data/svd/data_svd_{PREFIX_STR}.csv'

if not os.path.exists(SVD_DATA_FILENAME):
    print(f'Creating svd file for {PREFIX_STR}')
    create_svd_df(df=df_data, column_value=COLUMNS_TO_KEEP, ↴
↪ outstring=PREFIX_STR)
```

Creating svd file for columns-tempC-months-6\_7\_8\_9

## 0.2 SVD

```
[8]: print(f'Loading svd file for {PREFIX_STR}')
df_svd = pd.read_csv(SVD_DATA_FILENAME, index_col=0)
df_svd.index = pd.to_datetime(df_svd.index)

# df_svd = trunc_df(df_svd)
svd_A = np.array(df_svd)

# build matrix U, S, V
svd_U, svd_S, svd_V = np.linalg.svd(svd_A, full_matrices=False)
```

Loading svd file for columns-tempC-months-6\_7\_8\_9

### 0.2.1 Precision of SVD Reconstruction

```
[9]: # function to calculate and plot precision of svd reconstruction
def svd_precision(svd_S):
    SVD_PRECISION_FILENAME = f'{SVD_FOLDER_PATH}/{PREFIX_STR}_svd_precision.png'
    remove_file_if_exists(SVD_PRECISION_FILENAME)

    fig = go.Figure(
```

```

        data=[go.Bar(
            x=np.arange(np.size(svd_S)),
            y=np.cumsum(svd_S / np.sum(svd_S))
        )
    ]
)

fig.update_layout(
    title_text='SVD Precision',
    title_x=0.5,
    xaxis_title='Rank',
    yaxis_title='Precision',
    width=1485,
    height=450,
)
fig.update_yaxes(range=[0.5, 1])
fig.write_image(SVD_PRECISION_FILENAME)
fig.show()

```

[10]: # Calculating svd reconstruction precision  
`svd_precision(svd_S)`



## 0.2.2 Full Reconstruction & Lower Rank Reconstruction

[11]: # full reconstruction - matrix svd\_Ar  
`svd_Ar = np.dot(svd_U * svd_S, svd_V)`  
`print(f'Diff: {np.mean(np.abs(svd_A - svd_Ar))}')`

# lower rank reconstruction - matrix svd\_Ar  
`k = 5`  
`svd_Ar = np.dot(svd_U[:, :k] * svd_S[:k], svd_V[:k, :])`

`print(f'Diff reconstruction: {np.mean(np.abs(svd_A - svd_Ar))}')`

Diff: 4.188998126592169e-14

```
Diff reconstruction: 0.25611653474570456
```

### 0.2.3 Average SVD Error

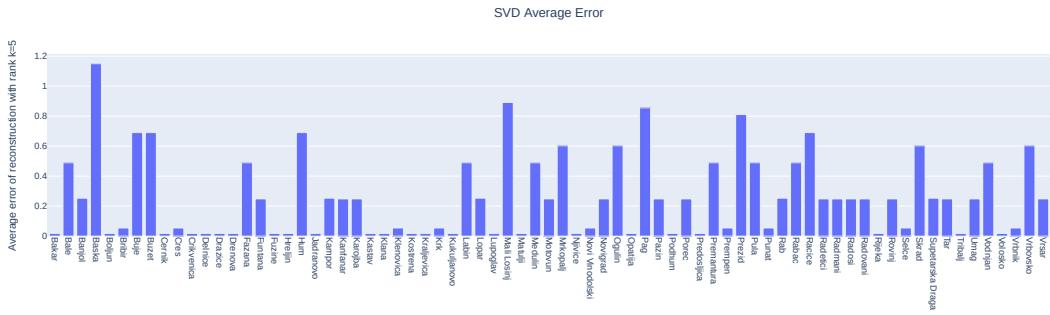
```
[12]: # function to calculate and plot average error of svd for k=n
def svd_average_error(svd_A, svd_Ar, k, unique_towns):
    SVD_AVG_ERR_FILENAME = f'{SVD_FOLDER_PATH}/{PREFIX_STR}_svd_avg_err.png'
    remove_file_if_exists(SVD_AVG_ERR_FILENAME)

    svd_err = np.average(np.abs(svd_A - svd_Ar), axis=0)
    asix_range = np.arange(0, len(unique_towns))

    fig = go.Figure(
        data=[
            go.Bar(
                x=asix_range,
                y=svd_err
            )
        ]
    )

    fig.update_layout(
        title_text='SVD Average Error', title_x=0.5,
        yaxis_title=f'Average error of reconstruction with rank k={k}',
        xaxis=dict(tickmode='array',
                   tickvals=asix_range,
                   ticktext=unique_towns
        ),
        width=1485,
        height=450,
    )
    fig.update_xaxes(tickangle=90)
    fig.write_image(SVD_AVG_ERR_FILENAME)
    fig.show()
```

```
[13]: # Calculating average error
svd_average_error(
    svd_A=svd_A,
    svd_Ar=svd_Ar,
    k=k,
    unique_towns=unique_towns
)
```



## 0.2.4 Dates to Concept - SVD\_U

```
[14]: # function to plot dates to concept for k=n
def svd_dates_to_concept(k, index, svd_U, trim=False):
    SVD_DTC_FILENAME = f'{SVD_FOLDER_PATH}/{PREFIX_STR}_svd_dates_to_concept.
    ↪png'
    remove_file_if_exists(SVD_DTC_FILENAME)

    fig = go.Figure()
    # if we have limited date range
    if trim == True:
        x_tmp = np.arange(0, len(index))
        for i in range(k):
            fig.add_trace(go.Scatter(
                x=x_tmp,
                y=svd_U[:, i], name=f'k={i}')
        )
        fig.update_layout(
            xaxis=dict(
                showticklabels=False,
            ),
            title=dict(
                text='Dates to Concept - Plotted as Continuous Function',
                x=0.5,
            )
        )
    # if we have full date range
    else:
        for i in range(k):
            fig.add_trace(go.Scatter(
                x=index,
                y=svd_U[:, i], name=f'k={i}')
        )
    fig.update_layout(
```

```

        title=dict(
            text='Dates to Concept',
            x=0.5,
        )
    )

fig.write_image(SVD_DTC_FILENAME)

fig.update_layout(
    xaxis=dict(
        rangeslider=dict(visible=True),
    ),
    width=1485,
    height=450,
)
fig.show()

```

[15]: # dates to concept

```

svd_dates_to_concept(
    k=k,
    index=df_svd.index,
    svd_U=svd_U,
)

```

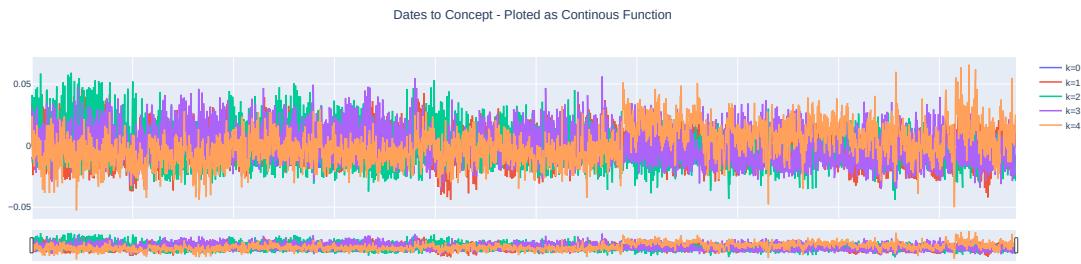


[16]: if 'months-' in PREFIX\_STR or 'years-' in PREFIX\_STR:

```

svd_dates_to_concept(
    k=k,
    index=df_svd.index,
    svd_U=svd_U,
    trim=True
)

```



### 0.2.5 Towns to Concept - SVD\_V

```
[17]: # function to plot towns to concept for k=n
def svd_towns_to_concept(k, svd_V, unique_towns, type='bar'):
    SVD_TTC_FILENAME = f'{SVD_FOLDER_PATH}/{PREFIX_STR}_svd_towns_to_concept.
    ↪png'
    remove_file_if_exists(SVD_TTC_FILENAME)

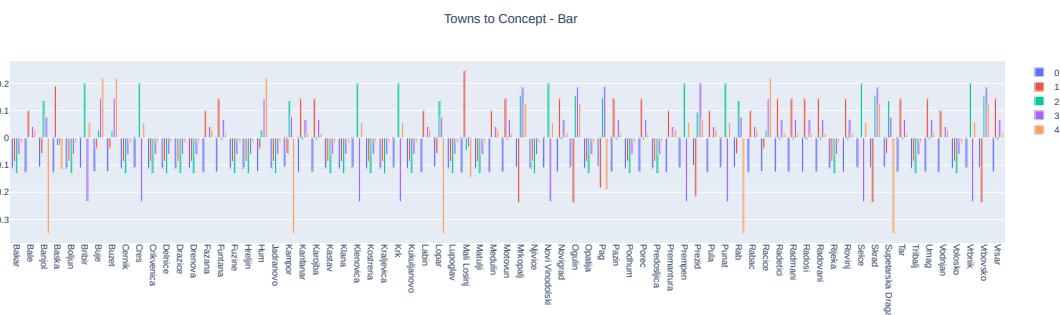
    asix_range = np.arange(0, len(unique_towns))
    all_plots = []
    for i in range(k):
        if type == 'bar':
            all_plots.append(go.Bar(x=asix_range, y=svd_V[i, :], name=f'{i}'))
        elif type == 'lines':
            all_plots.append(go.Scatter(mode='lines', x=asix_range, y=svd_V[i, :],
    ↪], name=f'{i}'))

    fig = go.Figure(data=all_plots)

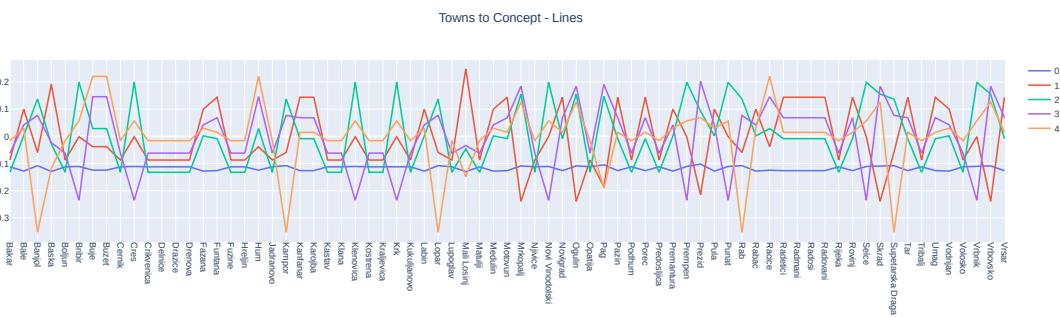
    fig.update_layout(
        title_text=f'Towns to Concept - {type.capitalize()}',
        title_x=0.5,
        xaxis=dict(
            tickmode='array',
            tickvals=asix_range,
            ticktext=unique_towns
        ),
        width=1485,
        height=450,
    )

    fig.update_xaxes(tickangle=90)
    fig.write_image(SVD_TTC_FILENAME)
    fig.show()
```

```
[18]: # towns to concept
        svd_towns_to_concept(
            k=k,
            svd_V=svd_V,
            unique_towns=unique_towns
        )
```



```
[19]: # towns to concept
        svd_towns_to_concept(
            k=k,
            svd_V=svd_V,
            unique_towns=unique_towns,
            type='lines'
        )
```



### 0.2.6 Singular Vector - SVD\_S

```
[20]: ' ; '.join(map(str, svd_S))
```

[20]: '12923.14927249107; 711.1366269352964; 530.2114560202634; 377.99376273110187;  
178.21499707261978; 178.06354093222149; 150.07240724935153; 115.35718796504129;  
83.43561139927718; 71.11554051415392; 67.96297970598685; 4.450879807025326e-12;

### 0.2.7 SVD Maps

```
[21]: # plot map with values from SVD_V (towns to concept)
def plot_svd_map(vector, k, data_geo):
    SVD_MAP_FILENAME = f'{SVD_FOLDER_PATH}/{PREFIX_STR}_svd_map_k{k}.png'
    remove_file_if_exists(SVD_MAP_FILENAME)

    data_geo['VALUES'] = vector
    px.set_mapbox_access_token(open(".mapbox_token").read())

    fig = px.scatter_mapbox(
        data_geo,
        size = [2] * len(data_geo.index),
        lat="LAT",
        lon="LNG",
        color="VALUES",
        hover_name="CITY",
        color_continuous_scale=px.colors.cyclical.Phase,
    )

    fig.update_layout(
        width=1485,
        height = 700,
        margin = {
            'l':5,
```

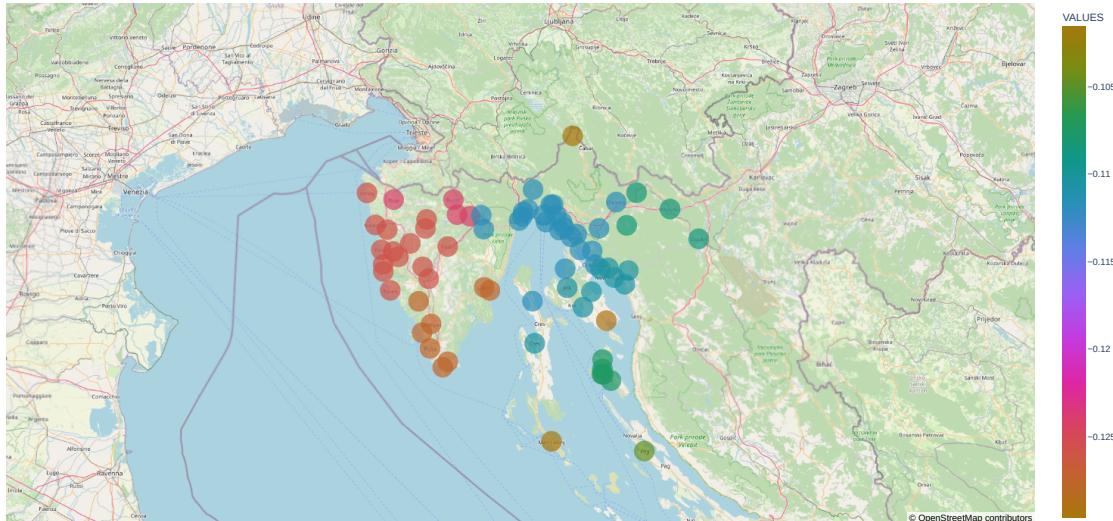
```

        'r':5,
        't':5,
        'b':5,
    },
    autosize=True,
    mapbox = {
        'style': "open-street-map",
        'zoom': 7.5
    }
)
fig.write_image(SVD_MAP_FILENAME)
fig.show()

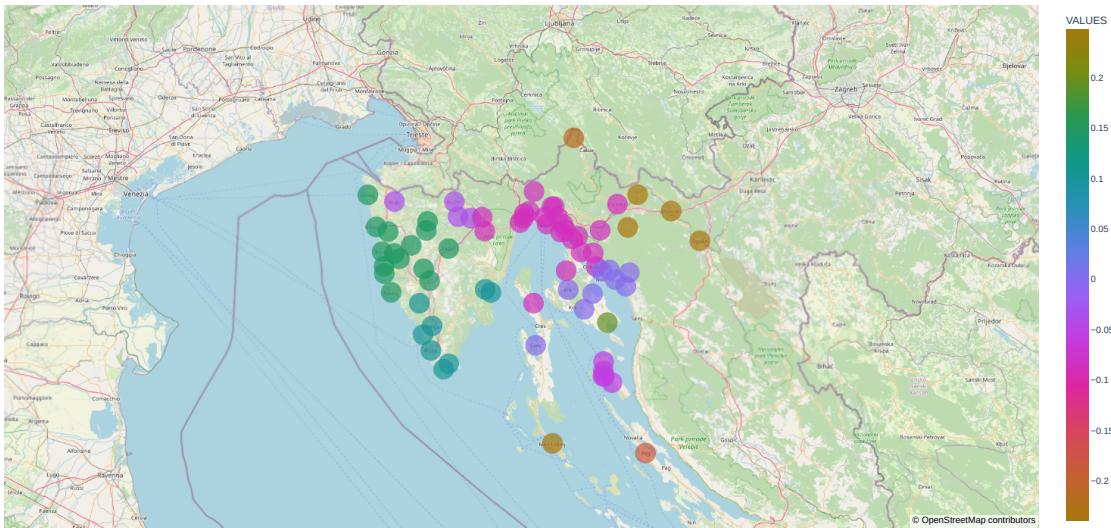
```

```
[22]: # plot maps
for i in range(k):
    print(f'Plotting map for k = {i}')
    plot_svd_map(
        vector=svd_V[i, :],
        k=i,
        data_geo=df_geolocation.copy()
    )
```

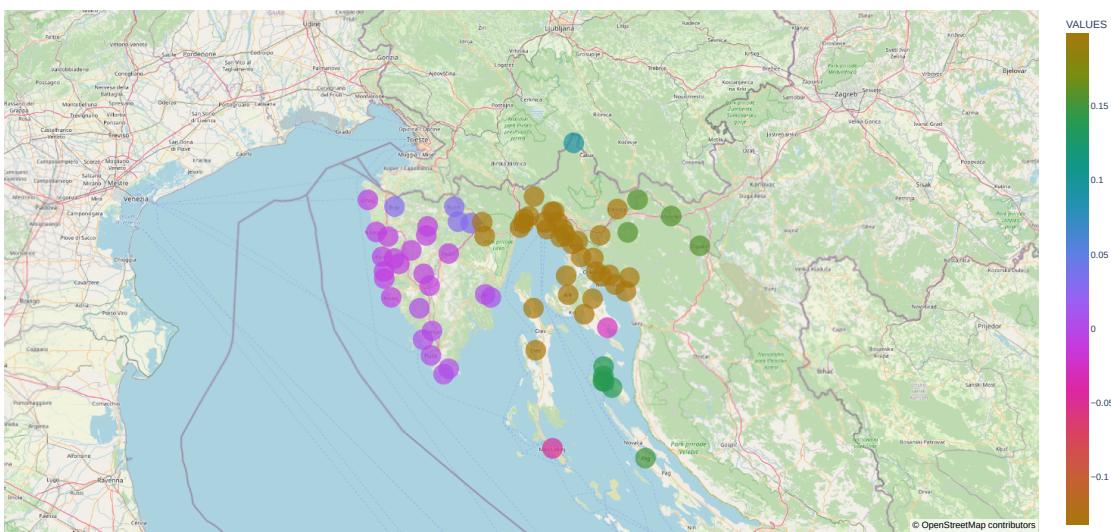
Plotting map for k = 0



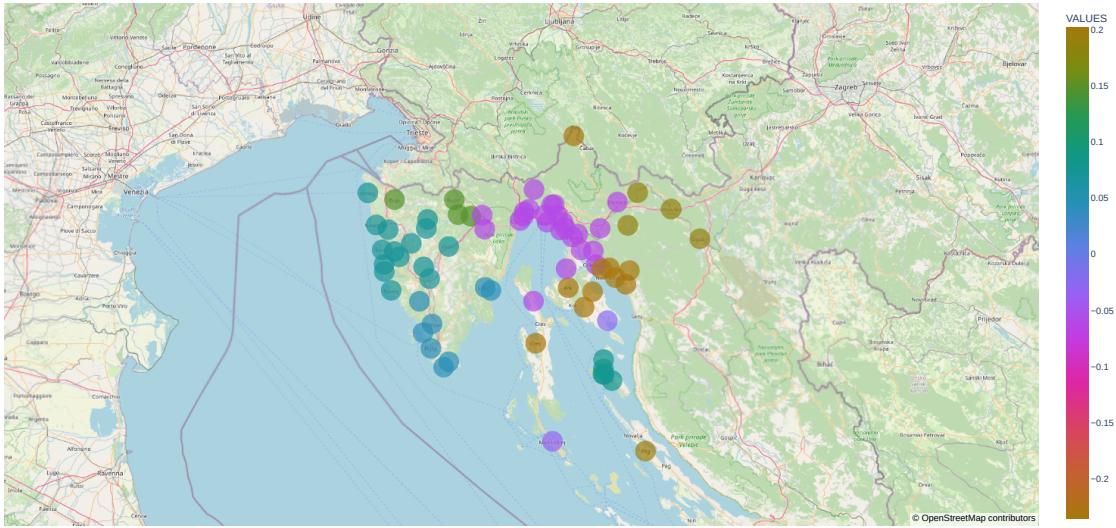
Plotting map for k = 1



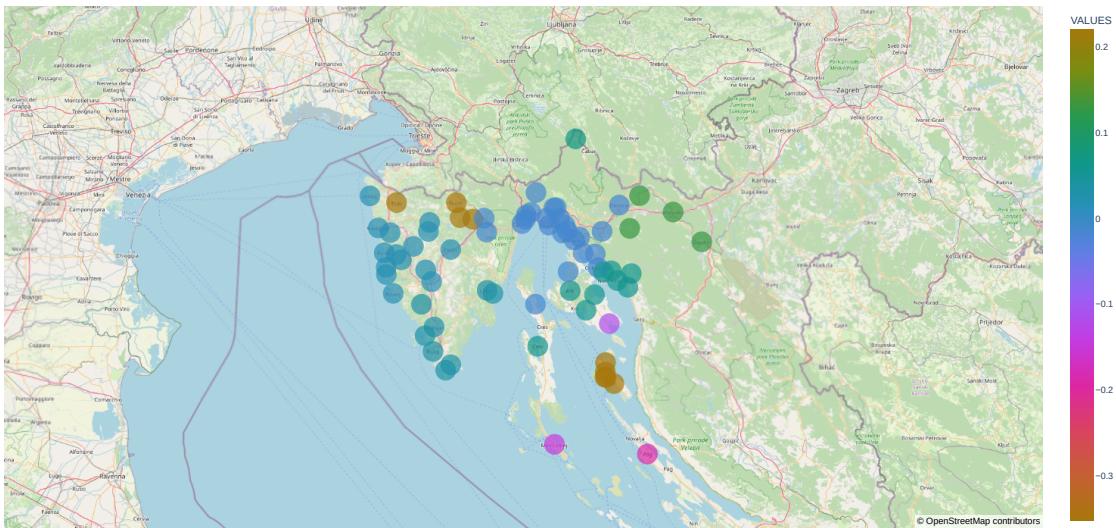
Plotting map for  $k = 2$



Plotting map for  $k = 3$



Plotting map for  $k = 4$



## 1 Export to HTML

```
[23]: # save notebook before nbconvert
import IPython
import time

# wait few sec for plot above to finish
time.sleep(3)
```

```
[24]: %%javascript  
IPython.notebook.save_notebook()
```

```
<IPython.core.display.Javascript object>
```

```
[25]: # export notebook results to HTML  
jupyter_out_filename = f'{PREFIX_STR}_svd'  
!jupyter nbconvert --output-dir 'output' --output {jupyter_out_filename}  
    --to=HTML svd.ipynb  
!jupyter nbconvert --output-dir 'output' --output {jupyter_out_filename}  
    --to=pdf svd.ipynb  
  
jupyter_out_filename_no_code = f'{PREFIX_STR}_svd_no_code'  
!jupyter nbconvert --output-dir 'output' --output  
    {jupyter_out_filename_no_code} --no-input --to=HTML svd.ipynb  
!jupyter nbconvert --output-dir 'output' --output  
    {jupyter_out_filename_no_code} --no-input --to=pdf svd.ipynb
```

```
[NbConvertApp] Converting notebook svd.ipynb to HTML  
[NbConvertApp] Writing 6176866 bytes to output/columns-tempC-  
months-6_7_8_9_svd.html
```