Week 9 Centrograph

March 8, 2021

1 Week 9 Group Assignment

Notebook 1: KDE and centrograph for housing affordability in New York Metro Area

For this week's group assignment, we are submitting two notebooks, each countaining spatial data analysis from one of the group members.

In this notebook, I explored and compared the spatial distribution of housing affordability change in New York Metro Area for owner-occupied housing units and rental units.

I also reviewed the interactive mapping from last week's lecture, and created an interactive map to show the housing affordability change for owner-occupied housing units. Users can choose percent of affordability change from the drop down menu, and the function will create map and charts show the counties with corresponding affordability changes.

1.1 Basic data analysis and exploration

This assignment is built on past weeks' assignment, and I combined some cells for the data exploration I've already conducted.

[11]:
```
#import libraries
import pandas as pd
import geopandas as gpd
import matplotlib.pyplot as plt
import plotly.express as px
import contextily as ctx
from sodapy import Socrata
import ipywidgets as widgets
from ipywidgets import interact, interact_manual
# new for data viz
import seaborn as sns

# to explore point patterns
from pointpats import centrography
from matplotlib.patches import Ellipse
import numpy
```

[7]:
```
#use .read_csv command to import 2014 ACS survey housing affordability data
hao2014 = pd.read_csv('hao2014.csv')
#import 2018 ACS survey housing affordability data
```

```
hao2018 = pd.read_csv('hao2018.csv')
```

[8]:
```
#drop the first row (row 0)
hao2014 = hao2014.drop([0])
hao2018 = hao2018.drop([0])
```

[9]:
```
#convert FIPS from object to integer so that I can merge the 2014 housing␣
 ↪affordability dataframe with county boundary dataframe
hao2014['FIPS'] = hao2014['FIPS'].astype(str).astype(int)
hao2018['FIPS'] = hao2018['FIPS'].astype(str).astype(int)
```

[10]:
```
#rename some of the columns to avoid repetition with hao2014 data
hao2018.columns=['GEO_ID',
 'NAME',
 'FIPS',
 'DP04_0080E',
 'DP04_0081E',
 'DP04_0081PE',
 'DP04_0082E',
 'DP04_0082PE',
 'DP04_0083E',
 'DP04_0083PE',
 'DP04_0084E',
 'DP04_0084PE',
 'DP04_0085E',
 'DP04_0085PE',
 'DP04_0086E',
 'DP04_0086PE',
 'DP04_0087E',
 'DP04_0087PE',
 'DP04_0088E',
 'DP04_0088PE',
 'DP04_0089E',
 'DP04_0090PE',
 'DP04_0091E',
 'DP04_0091PE',
 'DP04_0092E',
 'DP04_0092PE',
 'DP04_0093E',
 'DP04_0093PE',
 'DP04_0094E',
 'DP04_0094PE',
 'DP04_0098E',
 'DP04_0098PE',
 'DP04_0099E',
 'DP04_0099PE',
 'DP04_0100E',
```

```
'DP04_0100PE',
'DP04_0098E.1',
'DP04_0098PE.1',
'DP04_0099E.1',
'DP04_0099PE.1',
'DP04_0100E.1',
'DP04_0100PE.1',
'DP04_0102E',
'DP04_0103E',
'DP04_0103PE',
'DP04_0104E',
'DP04_0104PE',
'DP04_0105E',
'DP04_0105PE',
'DP04_0106E',
'DP04_0106PE',
'DP04_0107E',
'DP04_0107PE',
'DP04_0108E_y',
'DP04_0108PE_y',
'DP04_0109E_y',
'DP04_0110E_y',
'DP04_0110PE_y',
'DP04_0111E_y',
'DP04_0111PE_y',
'DP04_0112E_y',
'DP04_0112PE_y',
'DP04_0113E_y',
'DP04_0113PE_y',
'DP04_0114E_y',
'DP04_0114PE_y',
'DP04_0115E_y',
'DP04_0115PE_y',
'DP04_0116E_y',
'DP04_0117E_y',
'DP04_0120E_y',
'DP04_0120PE_y',
'DP04_0121E',
'DP04_0121PE',
'DP04_0122E',
'DP04_0122PE',
'DP04_0123E',
'DP04_0123PE',
'DP04_0124E',
'DP04_0124PE',
'DP04_0125E',
'DP04_0126E',
```

```
 'DP04_0127E',
 'DP04_0127PE',
 'DP04_0128E',
 'DP04_0128PE',
 'DP04_0129E',
 'DP04_0129PE',
 'DP04_0130E',
 'DP04_0130PE',
 'DP04_0131E',
 'DP04_0131PE',
 'DP04_0132E',
 'DP04_0132PE',
 'DP04_0133E',
 'DP04_0133PE',
 'DP04_0134E',
 'DP04_0135E',
 'Unnamed: 98',
 'DP04_0137E',
 'DP04_0137PE',
 'DP04_0138E',
 'DP04_0138PE',
 'DP04_0139E',
 'DP04_0139PE',
 'DP04_0140E',
 'DP04_0140PE',
 'DP04_0141E',
 'DP04_0141PE',
 'DP04_0142E',
 'DP04_0142PE',
 'DP04_0143E']
```

[14]:
```
#import county boundary data set
tracts=gpd.read_file('Countyborder/tl_2017_us_county.shp')
tracts['FIPS']=tracts['GEOID']
tracts['FIPS'] = tracts['FIPS'].astype(str).astype(int)
```

[16]:
```
#merge tracts with hao2014 and hao2018 on FIPS
tracts2018=tracts.merge(hao2018,on="FIPS")
tracts2014=tracts.merge(hao2014,on="FIPS")
```

[17]:
```
#convert the data type of columns in 2014 housing affordability dataframe from␣
 ↪object to integers for mapping
tracts2014["DP04_0109E"] =tracts2014["DP04_0109E"].astype(str).astype(int)
tracts2014["DP04_0109PE"] =tracts2014["DP04_0109PE"].astype(float).astype(int)
tracts2014["DP04_0110E"] =tracts2014["DP04_0110E"].astype(str).astype(int)
tracts2014["DP04_0110PE"] =tracts2014["DP04_0110PE"].astype(float).astype(int)
tracts2014["DP04_0111E"] =tracts2014["DP04_0111E"].astype(float).astype(int)
```

```
tracts2014["DP04_0111PE"] =tracts2014["DP04_0111PE"].astype(float).astype(int)
tracts2014["DP04_0112E"] =tracts2014["DP04_0112E"].astype(float).astype(int)
tracts2014["DP04_0112PE"] =tracts2014["DP04_0112PE"].astype(float).astype(int)
tracts2014["DP04_0113E"] =tracts2014["DP04_0113E"].astype(float).astype(int)
tracts2014["DP04_0113PE"] =tracts2014["DP04_0113PE"].astype(float).astype(int)
tracts2014["DP04_0114E"] =tracts2014["DP04_0114E"].astype(float).astype(int)
```

[18]:
```
#convert the data type of columns in 2018 housing affordability dataframe from␣
 ↪object to integers for mapping
tracts2018["DP04_0111E_y"] =tracts2018["DP04_0111E_y"].astype(str).astype(int)
tracts2018["DP04_0111PE_y"] =tracts2018["DP04_0111PE_y"].astype(float).
 ↪astype(int)
tracts2018["DP04_0112E_y"] =tracts2018["DP04_0112E_y"].astype(str).astype(int)
tracts2018["DP04_0112PE_y"] =tracts2018["DP04_0112PE_y"].astype(float).
 ↪astype(int)
tracts2018["DP04_0113E_y"] =tracts2018["DP04_0113E_y"].astype(float).astype(int)
tracts2018["DP04_0113PE_y"] =tracts2018["DP04_0113PE_y"].astype(float).
 ↪astype(int)
tracts2018["DP04_0114E_y"] =tracts2018["DP04_0114E_y"].astype(float).astype(int)
tracts2018["DP04_0114PE_y"] =tracts2018["DP04_0114PE_y"].astype(float).
 ↪astype(int)
tracts2018["DP04_0115E_y"] =tracts2018["DP04_0115E_y"].astype(float).astype(int)
tracts2018["DP04_0115PE_y"] =tracts2018["DP04_0115PE_y"].astype(float).
 ↪astype(int)
tracts2018["DP04_0116E_y"] =tracts2018["DP04_0116E_y"].astype(float).astype(int)
```

[19]:
```
#calculating the SMOCAPI<30 for 2014 and 2018 by adding three SMOCAPI␣
 ↪categories
tracts2014['SMOCAPI1430']=␣
 ↪tracts2014['DP04_0109PE']+tracts2014['DP04_0110PE']+tracts2014['DP04_0111PE']
tracts2018['SMOCAPI1830']=␣
 ↪tracts2018['DP04_0111PE_y']+tracts2018['DP04_0112PE_y']+tracts2018['DP04_0113PE_y']
```

[20]:
```
tracts2018['ac']=tracts2018['SMOCAPI1830']-tracts2014['SMOCAPI1430']
```

[36]:
```
#convert data type from object to integer for later calculation
tracts2014["DP04_0135PE"] =tracts2014["DP04_0135PE"].astype(float).astype(int)
tracts2014["DP04_0136PE"] =tracts2014["DP04_0136PE"].astype(float).astype(int)
tracts2014["DP04_0137PE"] =tracts2014["DP04_0137PE"].astype(float).astype(int)
tracts2014["DP04_0138PE"] =tracts2014["DP04_0138PE"].astype(float).astype(int)
tracts2018["DP04_0137PE"] =tracts2018["DP04_0137PE"].astype(float).astype(int)
tracts2018["DP04_0138PE"] =tracts2018["DP04_0138PE"].astype(float).astype(int)
tracts2018["DP04_0139PE"] =tracts2018["DP04_0139PE"].astype(float).astype(int)
tracts2018["DP04_0140PE"] =tracts2018["DP04_0140PE"].astype(float).astype(int)
```

[37]:
```
#calculate housing affordability change for rental housing units between 2014␣
 ↪and 2018
tracts2014['GRAPI1430']=␣
 ↪tracts2014['DP04_0135PE']+tracts2014['DP04_0136PE']+tracts2014['DP04_0137PE']+tracts2014['D
tracts2018['GRAPI1830']=␣
 ↪tracts2018['DP04_0137PE']+tracts2018['DP04_0138PE']+tracts2018['DP04_0139PE']+tracts2018['D
tracts2018['rac']=tracts2018['GRAPI1830']-tracts2014['GRAPI1430']
#get top 5 (radt5) and bottom 5 (racb5) counties in NYMA experienced most and␣
 ↪least amount of changes in affordability
ract5=tracts2018 .sort_values(by='rac',ascending = False).head(5)
racb5=tracts2018 .sort_values(by='rac',ascending = False).tail(5)
#create new dataframe by combining the top 5 and bottom 5 counties for plotting
raffordability=ract5.append(racb5)
```

1.2 Interactive map for owner-occupied housing affordability change

[22]:
```
#let's zoom in to find the counties with housing affordability change equals to␣
 ↪7
tracts2018[tracts2018.ac == 7.0].head()
```

[22]:

	STATEFP	COUNTYFP	COUNTYNS	GEOID	NAME_x	NAMELSAD	LSAD	CLASSFP	\
10	42	089	01209184	42089	Monroe	Monroe County	06	H1	
13	34	025	00882910	34025	Monmouth	Monmouth County	06	H1	
15	34	029	00882279	34029	Ocean	Ocean County	06	H1	
18	34	027	00882231	34027	Morris	Morris County	06	H1	
19	34	013	00882276	34013	Essex	Essex County	06	H1	

	MTFCC	CSAFP	…	DP04_0139PE	DP04_0140E	DP04_0140PE	DP04_0141E	\
10	G4020	408	…	11.1	1599	13.8	1246	
13	G4020	408	…	12.3	6236	10.8	4731	
15	G4020	408	…	9.4	5104	12.2	3633	
18	G4020	408	…	15	5372	12.1	3646	
19	G4020	408	…	11.1	17135	11.4	14663	

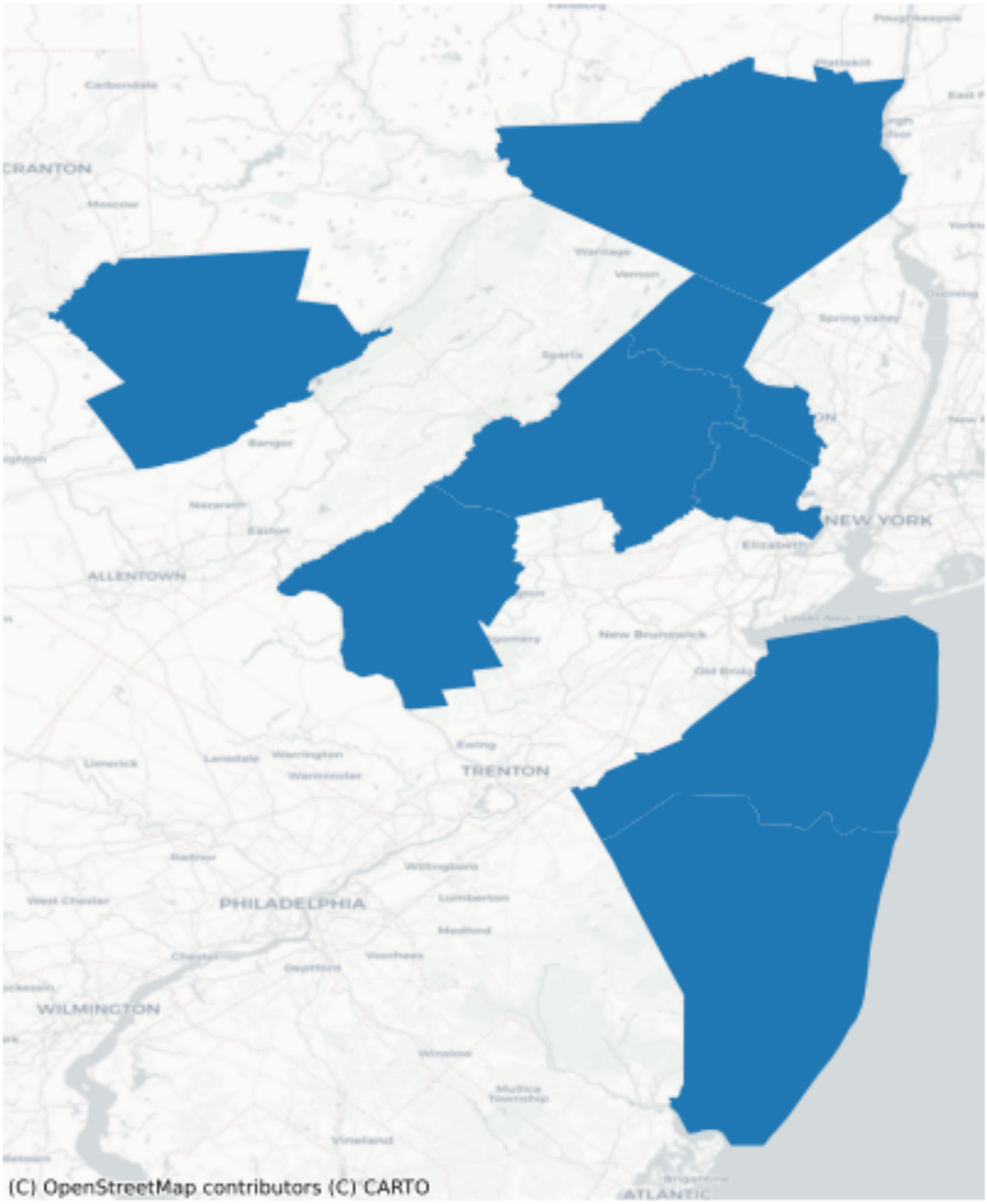
	DP04_0141PE	DP04_0142E	DP04_0142PE	DP04_0143E	SMOCAPI1830	ac
10	10.7	4780	41.2	1044	60	7
13	8.2	27317	47.2	3665	63	7
15	8.7	21638	51.7	3255	58	7
18	8.2	15316	34.6	1973	66	7
19	9.7	69401	46	6880	56	7

[5 rows x 132 columns]

I want to create an interactive map that shows different counties with various level of housing affordability change: people can choose different percentage of housing affordability change ("ac" category) and show the counties.

[23]:
```
#plot those counties onto the map
display(tracts2018[tracts2018.ac == 7].head())

# map
ax = tracts2018[tracts2018.ac == 7].plot(figsize=(9,9))

# axis
ax.axis('off')

# basemap
ctx.add_basemap(ax,
                crs='epsg:4326',
                source=ctx.providers.CartoDB.Positron) #change the base map
```

```
   STATEFP COUNTYFP  COUNTYNS  GEOID    NAME_x         NAMELSAD LSAD CLASSFP  \
10      42       089  01209184  42089    Monroe    Monroe County   06      H1
13      34       025  00882910  34025  Monmouth  Monmouth County   06      H1
15      34       029  00882279  34029     Ocean     Ocean County   06      H1
18      34       027  00882231  34027    Morris    Morris County   06      H1
19      34       013  00882276  34013     Essex     Essex County   06      H1

    MTFCC CSAFP  … DP04_0139PE DP04_0140E DP04_0140PE  DP04_0141E  \
10  G4020   408  …        11.1       1599        13.8        1246
13  G4020   408  …        12.3       6236        10.8        4731
15  G4020   408  …         9.4       5104        12.2        3633
18  G4020   408  …          15       5372        12.1        3646
19  G4020   408  …        11.1      17135        11.4       14663

    DP04_0141PE DP04_0142E DP04_0142PE DP04_0143E  SMOCAPI1830 ac
10         10.7       4780        41.2       1044           60  7
13          8.2      27317        47.2       3665           63  7
15          8.7      21638        51.7       3255           58  7
18          8.2      15316        34.6       1973           66  7
19          9.7      69401          46       6880           56  7

[5 rows x 132 columns]
```



[24]:
```
# create a function to show housing affordability chang on the map
def affordabilitychange_by(ac=7):
    # table
    display(tracts2018[tracts2018.ac == ac].head())

    # map
    ax = tracts2018[tracts2018.ac == ac].plot(figsize=(9,9))
```

```
    # axis
    ax.axis('off')

    # basemap
    ctx.add_basemap(ax,
                    crs='epsg:4326',
                    source=ctx.providers.CartoDB.Positron)
```

[27]:
```
#make the map and charts interactive
@interact

def affordabilitychange_by(ac=(2,9)): #change the range of the slider
    # table
    display(tracts2018[tracts2018.ac == ac].head())

    # map
    ax = tracts2018[tracts2018.ac == ac].plot(figsize=(9,9),␣
 ↪color='wheat',alpha=0.5,edgecolor='k')

    # axis
    ax.axis('off')

    # basemap
    ctx.add_basemap(ax,
                    crs='epsg:4326',
                    source=ctx.providers.CartoDB.Positron)
```

```
interactive(children=(IntSlider(value=5, description='ac', max=9, min=2),␣
 ↪Output()), _dom_classes=('widget-int…
```

1.3 Spatial data analysis of owner-occupied and rental housing affordability change

1.3.1 KDE plots

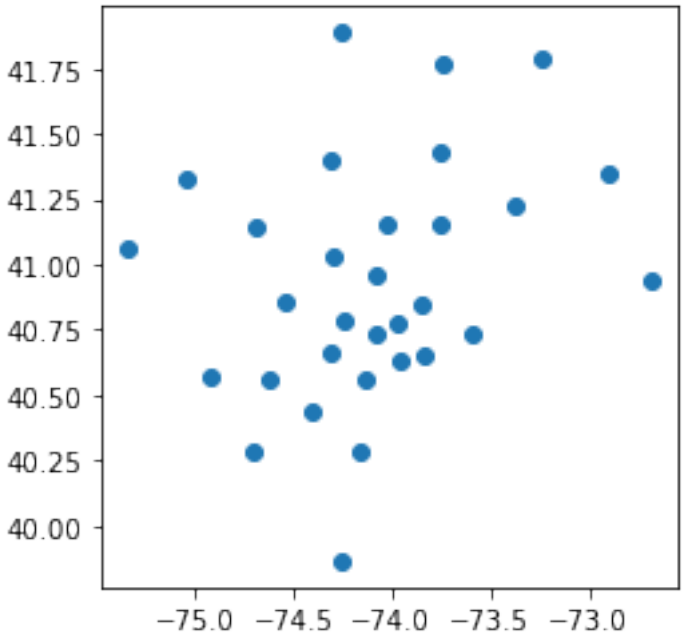
[29]:
```
#identify centroid of polygons and create a new polygon
tracts2018['cents'] = tracts2018.centroid
tracts2018.head()
```

```
<ipython-input-29-becea95e7fa1>:2: UserWarning: Geometry is in a geographic CRS.
Results from 'centroid' are likely incorrect. Use 'GeoSeries.to_crs()' to re-
project geometries to a projected CRS before this operation.

  tracts2018['cents'] = tracts2018.centroid
```

[29]:
```
  STATEFP COUNTYFP  COUNTYNS  GEOID    NAME_x         NAMELSAD LSAD CLASSFP  \
0      34      037  00882236  34037    Sussex    Sussex County   06      H1
1      36      111  00974153  36111    Ulster    Ulster County   06      H1
2      36      103  00974149  36103   Suffolk   Suffolk County   06      H1
3      34      039  00882235  34039     Union     Union County   06      H1
4      36      027  00974112  36027  Dutchess  Dutchess County   06      H1

   MTFCC CSAFP  … DP04_0140E DP04_0140PE DP04_0141E  DP04_0141PE  \
0  G4020   408  …       1018        11.8        815          9.5
1  G4020   408  …       1716         8.6       2111         10.5
2  G4020   408  …       9917          11       8180          9.1
3  G4020   408  …       8186        11.1       6691            9
4  G4020   408  …       3021         9.6       2754          8.8

   DP04_0142E DP04_0142PE DP04_0143E SMOCAPI1830  ac  \
0        3671        42.6        730          64   8
1        9862        49.2       1682          63   6
2       45855        50.9       6949          56   5
3       32639        44.1       3742          59   8
4       14591        46.4       2112          61   5

                       cents
0  POINT (-74.69080 41.13930)
1  POINT (-74.25857 41.88815)
2  POINT (-72.68524 40.94046)
3  POINT (-74.30814 40.65990)
4  POINT (-73.74286 41.76515)

[5 rows x 133 columns]
```

[30]:
```
#simple plot of the center points of each polygon
tracts2018.cents.plot()
```

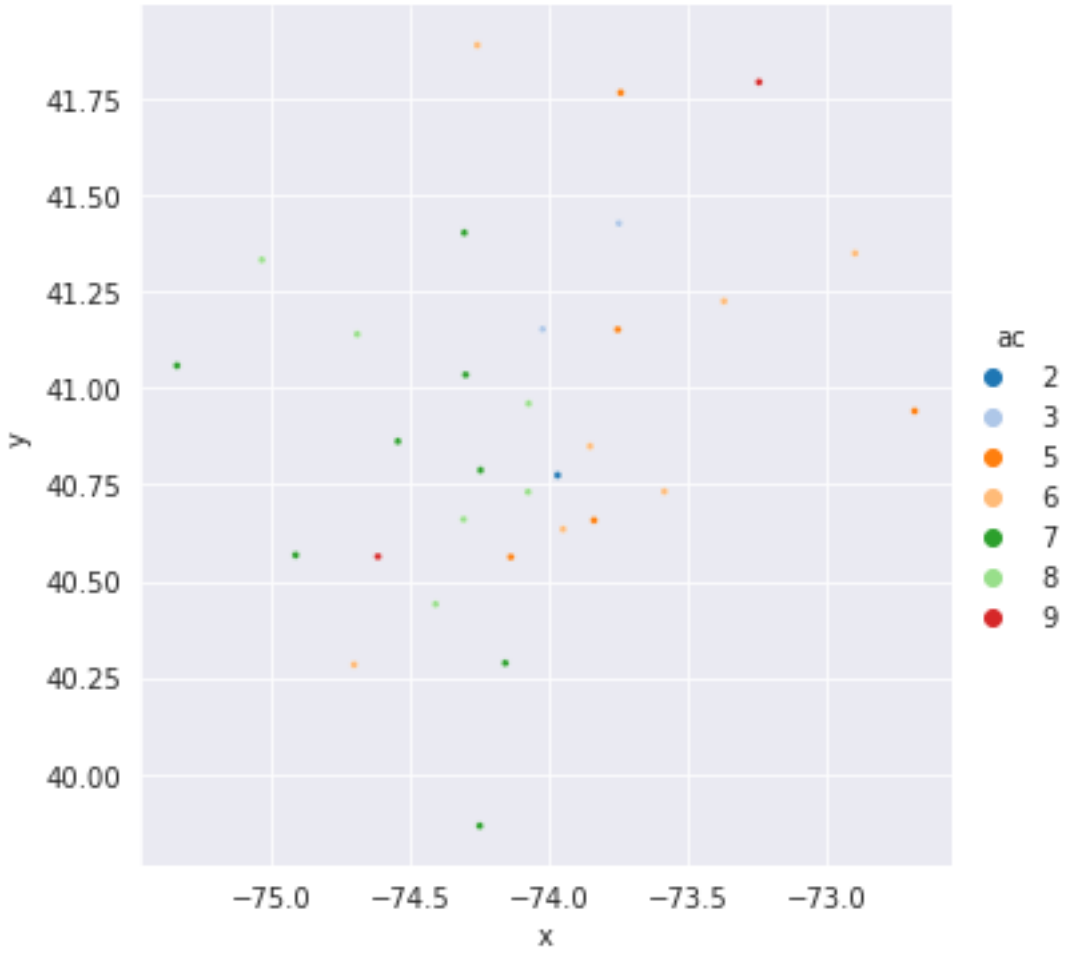
[30]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x7f9d2f8281c0>
```



[31]:
```
#extract latitude and longitude from center points and create two new columns
tracts2018['x'] = tracts2018.cents.x
tracts2018['y'] = tracts2018.cents.y
```

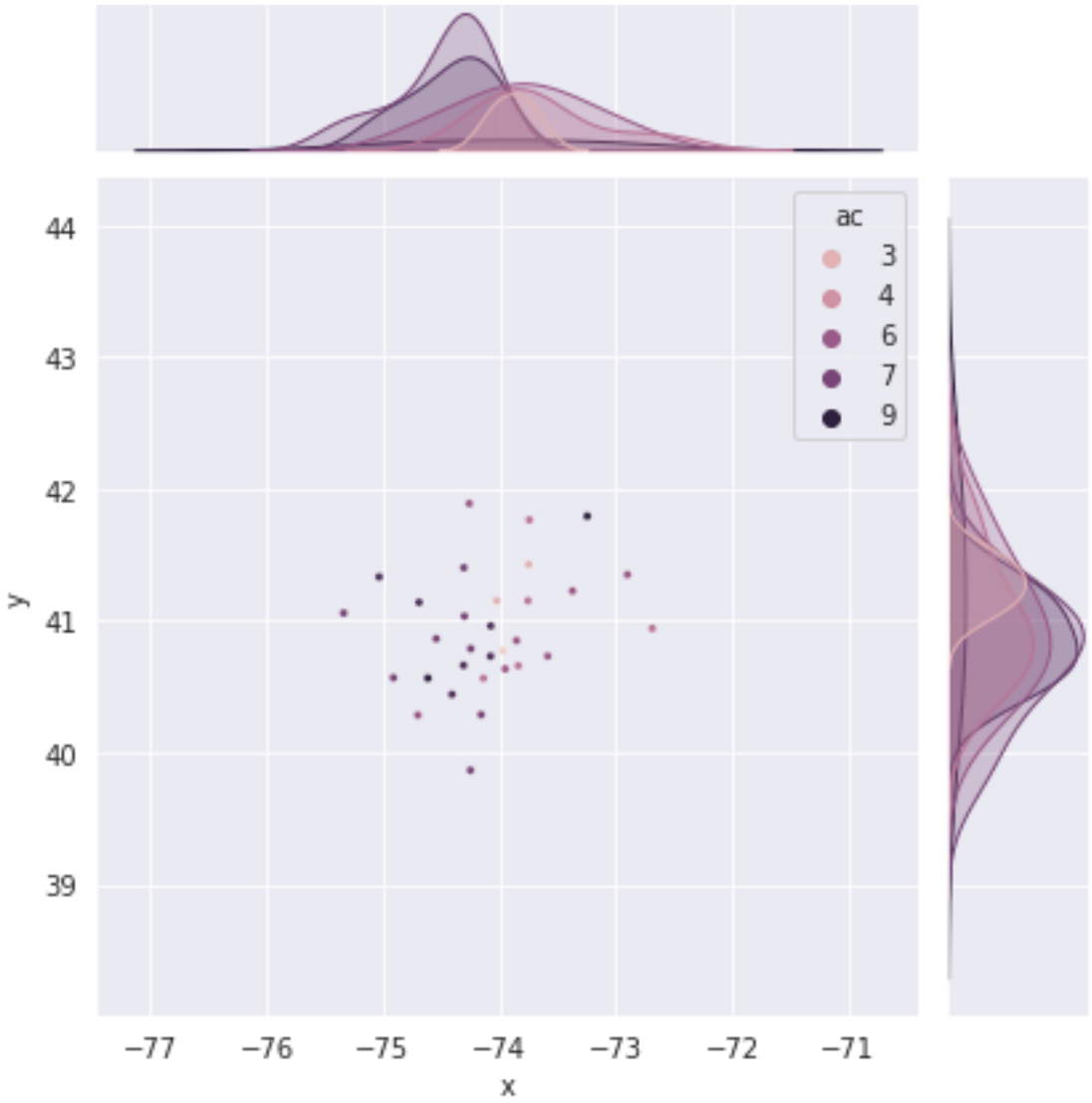
[32]:
```
#plot the center points of polygons with owner-occupied housing units'␣
 ↪affordability change
sns.set_style('darkgrid') #change the style of the plot
sns.relplot(data=tracts2018,
            x='x',
            y='y',
            hue='ac', #categories to plot
            palette='tab20',
            s=8)
```

[32]:
```
<seaborn.axisgrid.FacetGrid at 0x7f9d2f81cfd0>
```



[33]:
```
#look at the spatial distribution of the data
g = sns.jointplot(data = tracts2018,
                  x='x',
                  y='y',
                  hue='ac',
                  s=10)
```

```
/opt/conda/lib/python3.8/site-packages/seaborn/distributions.py:305:
UserWarning: Dataset has 0 variance; skipping density estimate.
  warnings.warn(msg, UserWarning)
/opt/conda/lib/python3.8/site-packages/seaborn/distributions.py:305:
UserWarning: Dataset has 0 variance; skipping density estimate.
  warnings.warn(msg, UserWarning)
```



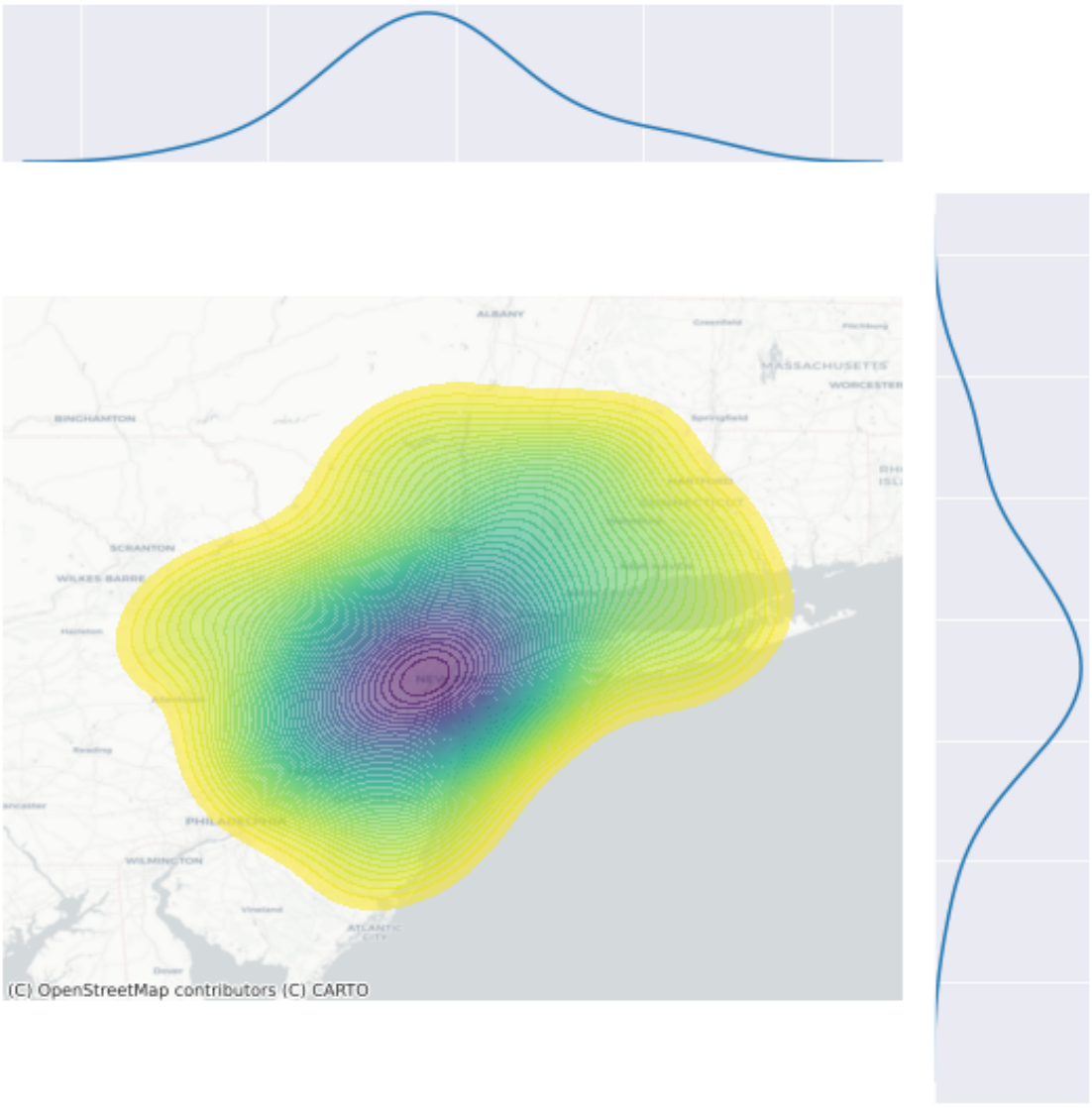
[34]:
```
#create a new dataframe with owner-occupied housing units' affordability change
gdf_ac = tracts2018[tracts2018.ac.isin([2,3,5,6,7,8,9])]
```

[38]:
```
#create a new dataframe with rental housing units' affordability change
gdf_rac = tracts2018[tracts2018.rac.isin([-2,-1,0,0,2,3,4,5,6,9])]
```

[39]:
```
#KDE plot for owner-occupied housing units' affordability change
g = sns.jointplot(data = gdf_ac,
                  x='x',
                  y='y',
                  kind='kde',
                  shade=True,
                  alpha=0.55,
```

```
                  cmap='viridis_r',
                  n_levels=50,
                  height=8 # make the map bigger
                 )
# Clean axes
g.ax_joint.set_axis_off()

# add basemap
ctx.add_basemap(g.ax_joint,
                crs='epsg:4326',
                source=ctx.providers.CartoDB.Positron)
```

[40]:
```
#KDE plot for rental housing units' affordability change
g1 = sns.jointplot(
                   data = gdf_rac,
                   x='x',
                   y='y',
                   kind='kde',
                   shade=True, #adding shade to the plot
                   alpha=0.55, #change transparency
                   cmap='viridis_r', #change color of the shade
                   n_levels=50,
                   height=8 # make the map bigger
                  )
g1.ax_joint.set_axis_off()
ctx.add_basemap(g1.ax_joint,
                crs='epsg:4326',
                source=ctx.providers.CartoDB.Positron)
```



Conclusion based on KDE plots From the KDE plots, the spatial distribution of affordability changes of owner-occupied units and rental units are roughly the same with highest concentration in New Jersey, around the counties to the north west of New York City. Both categories' concentrations decreases the fastest in the southeaster direction of the center.

1.3.2 Centrography Analysis

[42]:
```
#find spatial means and medians of two categories
mean_center0 = centrography.mean_center(gdf_ac[['x','y']])
med_center0 = centrography.euclidean_median(gdf_ac[['x','y']])
mean_center1 = centrography.mean_center(gdf_rac[['x','y']])
med_center1 = centrography.euclidean_median(gdf_rac[['x','y']])
```

[43]:
```
#plot the spatial distribution of owner-occupied units' housing affordability␣
 ↪change with mean and median
g = sns.jointplot(
    x='x', y='y', data=gdf_ac, s=10, height=9
)

# Add mean point and marginal lines
g.ax_joint.scatter(
    *mean_center0, color='red', marker='x', s=50, label='Mean Center'
)
g.ax_marg_x.axvline(mean_center0[0], color='red')
g.ax_marg_y.axhline(mean_center0[1], color='red')

# Add median point and marginal lines
g.ax_joint.scatter(
    *med_center0, color='limegreen', marker='o', s=50, label='Median Center'
)
g.ax_marg_x.axvline(med_center0[0], color='limegreen')
g.ax_marg_y.axhline(med_center0[1], color='limegreen')

# Legend
g.ax_joint.legend()

# Add basemap
ctx.add_basemap(
    g.ax_joint,
    crs='epsg:4326',
    source=ctx.providers.CartoDB.Positron
)

# Clean axes
g.ax_joint.set_axis_off()

# Display
plt.show()
```

[44]:
```
#generate the spatial distribution of rental units' housing affordability␣
 ↪change with mean and median
#generate scatter plot
g1 = sns.jointplot(
    x='x', y='y', data=gdf_rac, s=10, height=9
)

# Add mean point and marginal lines
g1.ax_joint.scatter(
    *mean_center0, color='red', marker='x', s=50, label='Mean Center'
)
g1.ax_marg_x.axvline(mean_center1[0], color='red')
```

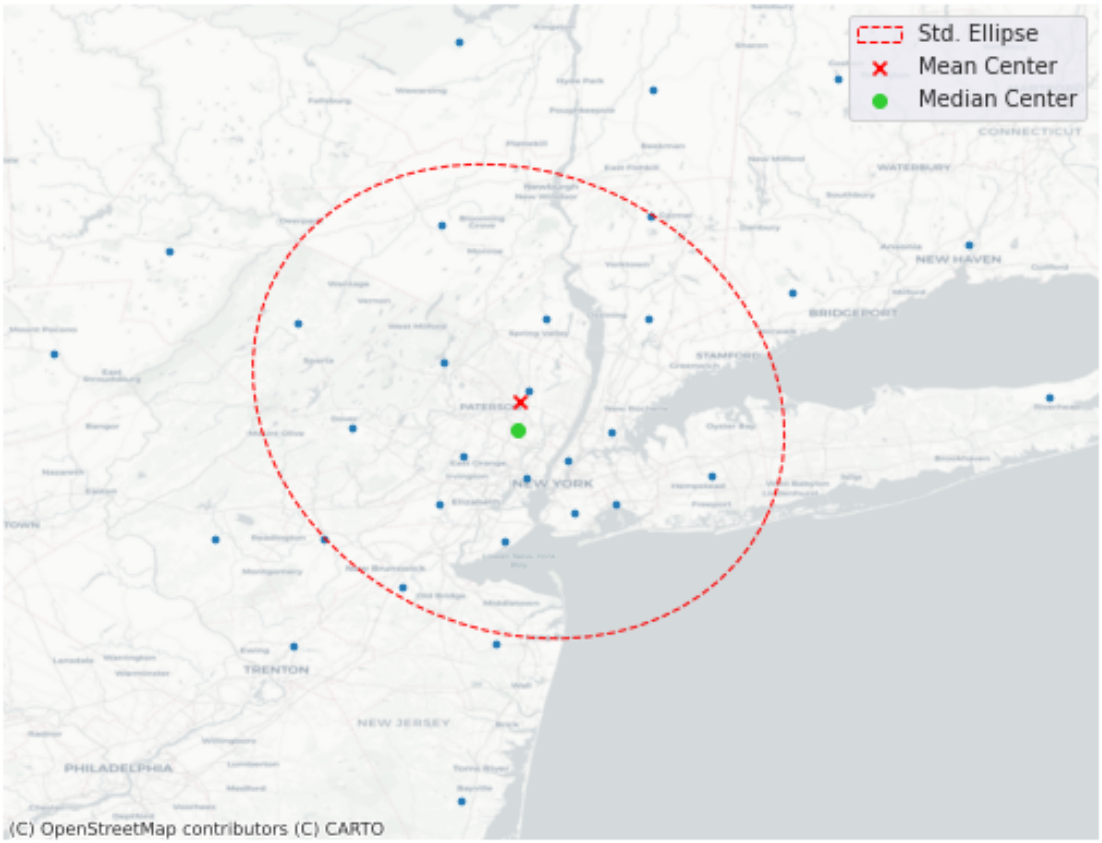
```
g1.ax_marg_y.axhline(mean_center1[1], color='red')

# Add median point and marginal lines
g1.ax_joint.scatter(
    *med_center0, color='limegreen', marker='o', s=50, label='Median Center'
)
g1.ax_marg_x.axvline(med_center1[0], color='limegreen')
g1.ax_marg_y.axhline(med_center1[1], color='limegreen')

# Legend
g1.ax_joint.legend()

# Add basemap
ctx.add_basemap(
    g1.ax_joint,
    crs='epsg:4326',
    source=ctx.providers.CartoDB.Positron
)

# Clean axes
g1.ax_joint.set_axis_off()

# Display
plt.show()
```

Conclusion from Centrography Analysis The discrepency between the two points in the above map is caused by the skew.there are many "clusters" of change in housing affordability far out in East and North NYMA, whereas South and West NYMA is densely packed, but drops off very quickly. Thus, the far out clusters of pictures pulls the mean center to the east and north, relative to the median center.

1.3.3 Dispersion

[46]:
```
# compute the axes and rotation using the ellipse function in pointpats for␣
↪owner-occupied housing units
major, minor, rotation = centrography.ellipse(gdf_ac[['x','y']])
```

[47]:
```
# Set up figure and axis
f, ax = plt.subplots(1, figsize=(9, 9))

ax.scatter(gdf_ac['x'], gdf_ac['y'], s=7)
ax.scatter(*mean_center0, color='red', marker='x', label='Mean Center')
ax.scatter(*med_center0, color='limegreen', marker='o', label='Median Center')

# Construct the standard ellipse using matplotlib
ellipse = Ellipse(xy=mean_center0, # center the ellipse on our mean center
                  width=major*2, # centrography.ellipse only gives half the axis
                  height=minor*2,
                  angle = numpy.rad2deg(rotation), # Angles for this are in␣
 ↪degrees, not radians
                  facecolor='none',
                  edgecolor='red',
                  linestyle='--',
                  label='Std. Ellipse')
ax.add_patch(ellipse)

ax.legend()

ax.axis('off')

# add a basemap
ctx.add_basemap(ax,
                crs='epsg:4326',
                source=ctx.providers.CartoDB.Positron)

# Display
plt.show()
```

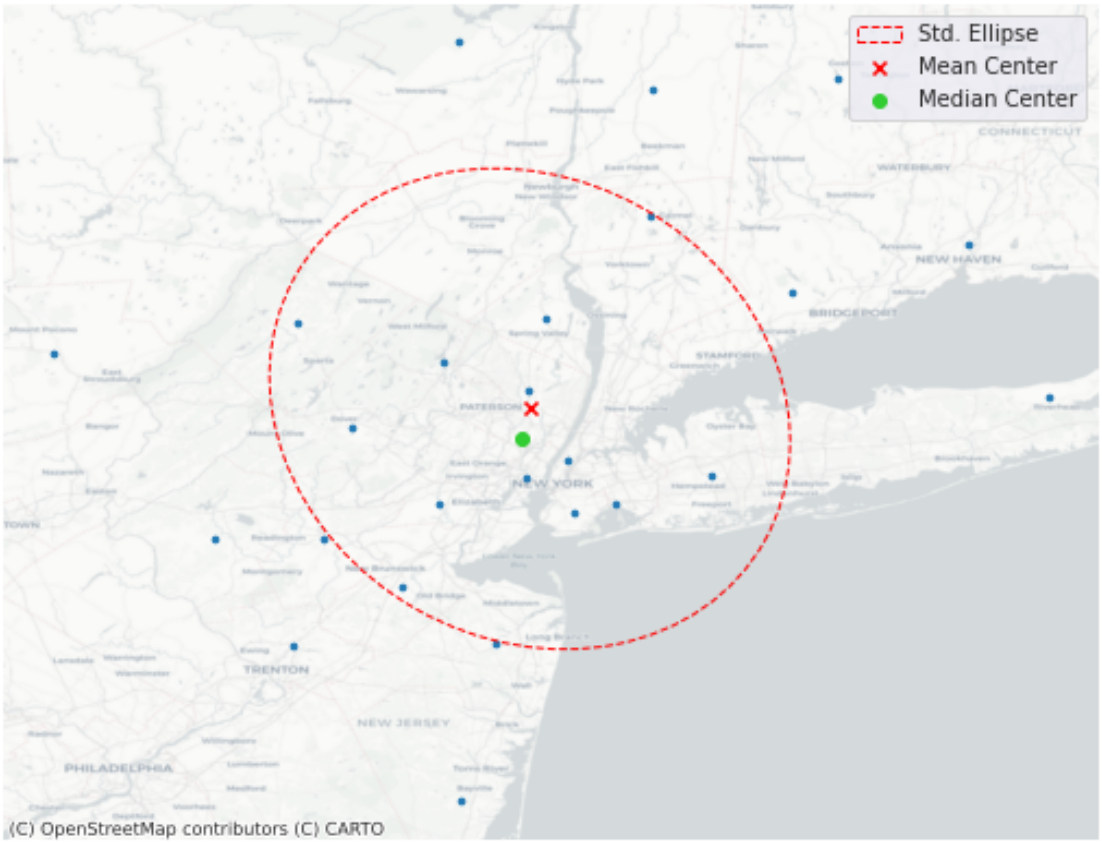


The standard deviation ecllipse shows the spatial spread of points on the map. The maximum spread of housing affordability change is roughly in the northwestern-southeastern direction, and the minimum spread of housing affordability change is roughly in the southwester-northeastern direction.

[48]:
```
# compute the axes and rotation using the ellipse function in pointpats for␣
↪rental housing units
major, minor, rotation = centrography.ellipse(gdf_rac[['x','y']])
```

[49]:
```
# set the style without grid lines
sns.set_style('dark')

# Set up figure and axis
f, ax = plt.subplots(1, figsize=(9, 9))

ax.scatter(gdf_rac['x'], gdf_rac['y'], s=7)
ax.scatter(*mean_center1, color='red', marker='x', label='Mean Center')
ax.scatter(*med_center1, color='limegreen', marker='o', label='Median Center')

# Construct the standard ellipse using matplotlib
```

```
ellipse = Ellipse(xy=mean_center1, # center the ellipse on our mean center
                  width=major*2, # centrography.ellipse only gives half the axis
                  height=minor*2,
                  angle = numpy.rad2deg(rotation), # Angles for this are in␣
 ↪degrees, not radians
                  facecolor='none',
                  edgecolor='red',
                  linestyle='--',
                  label='Std. Ellipse')

ax.add_patch(ellipse)

ax.legend()

ax.axis('off')

# add a basemap
ctx.add_basemap(ax,
                crs='epsg:4326',
                source=ctx.providers.CartoDB.Positron)

# Display
plt.show()
```



Compared with the centrography of owner-occupied housing units' affordability change, The maximum spread of rental units' housing affordability change is roughly in the same direction (northwestern-southeastern), and so does the the minimum spread (southwester-northeastern direction).

1.4 Contribution from each team member

For this assignment, two team members each conducted individual spatial analysis on the data we are working with.