t-SNE-MNIST-Digits-Dataset-Threaded

November 13, 2018

1 t-SNE on MNIST Handwritten Digits Dataset

```
In [1]: # import required modules
        import numpy as np # for matrix multiplication
        import matplotlib.pyplot as plt # for plotting
        import seaborn as sns # for plotting
        import pandas as pd              # for data handling
        from sklearn.preprocessing import StandardScaler # for column standardization
        from sklearn.manifold import TSNE # for t-SNE
        import time # for time measurement
        import multiprocessing # for threading
        import imageio # for GIF creation
```

```
In [2]: print(multiprocessing.cpu_count())
```

```
12
```

```
In [3]: # Read dataset
        #d0 = pd.read_csv('./../../AAIC-Course/datasets/mnist-digits-dataset/train.csv')
        d0 = pd.read_csv('./../../../datasets/mnist-digits-dataset/train.csv')
        d0.head()
```

```
Out[3]:    label  pixel0  pixel1  pixel2  pixel3  pixel4  pixel5  pixel6  pixel7  \
        0      1       0       0       0       0       0       0       0       0
        1      0       0       0       0       0       0       0       0       0
        2      1       0       0       0       0       0       0       0       0
        3      4       0       0       0       0       0       0       0       0
        4      0       0       0       0       0       0       0       0       0

           pixel8    ...     pixel774  pixel775  pixel776  pixel777  pixel778  \
        0       0    ...            0         0         0         0         0
        1       0    ...            0         0         0         0         0
        2       0    ...            0         0         0         0         0
        3       0    ...            0         0         0         0         0
        4       0    ...            0         0         0         0         0

           pixel779  pixel780  pixel781  pixel782  pixel783
        0         0         0         0         0         0
        1         0         0         0         0         0
        2         0         0         0         0         0
        3         0         0         0         0         0
        4         0         0         0         0         0

        [5 rows x 785 columns]
```

```
In [4]: # split the dataset into features and labels
        d_labels_all = d0['label']
        d_data_all = d0.drop('label',axis=1)
        print(d_labels_all.shape,d_data_all.shape)
```

```
(42000,) (42000, 784)
```

```
In [5]: def genTSNEGif(std_data, ndp, p, itr_list, img_name):
            '''
            Fuction which genrate t-SNE visualtion for each itr_list using given ndp and p
            Generates a GIF and stores it under '{img_name}.gif'
            Where:
            std_data - Column Standardized Data
            ndp - Number of Data Points to consider in std_data
            p - Perplexity
            itr_list - List of iterations, each iteration will be a frame in GIF
            img_name - Name of GIF image
            '''
```

```
    print('No.Of Data Points - {0}, Perplexity - {1}, Iterations - {2}, ImageName - {3}'.format(
         ndp, p, itr_list, img_name))

    # list to hold the frames
    frames = []

    p_data = standardized_data[0:ndp,:]
    p_labels = d_train_labels[0:ndp]
    #print('t-SNE Data Points {0} and its Labels {1}'.format(p_data.shape, p_labels.shape))

    for itr_val in itr_list:
        img_title = 'ndp={0} p={1} itr={2}'.format(ndp, p, itr_val)
        time_start = time.time()

        model = TSNE(n_components=2,random_state=0,perplexity=p,n_iter=itr_val)

        tsne_data = model.fit_transform(p_data)
        time_elapsed = time.time() - time_start
        print('{0} ==> t-SNE done! Time elapsed: {1} seconds'.format(img_title, time.time() - time_start))

        tsne_data = np.vstack((tsne_data.T,p_labels)).T
        #print(tsne_data.shape)
        #tsne_data[:4]

        tsne_df = pd.DataFrame(tsne_data,columns=['Dim_1','Dim_2','label'])
        #tsne_df.head()

        g = sns.FacetGrid(tsne_df,hue='label',height=10).map(plt.scatter, 'Dim_1', 'Dim_2').add_legend();

        g.fig.suptitle(img_title)
        g.fig.canvas.draw()

        image = np.frombuffer(g.fig.canvas.tostring_rgb(), dtype='uint8')
        image  = image.reshape(g.fig.canvas.get_width_height()[::-1] + (3,))

        frames.append(image)

    kwargs_write = {'fps':1.0, 'quantizer':'nq'}
    imageio.mimsave('./{}.gif'.format(img_name), frames, fps=1)

    return
```

1.1 Training Size - 15000

```
In [ ]: # Taking 15000 images for training
        training_size = 15000

        d_train_labels = d_labels_all.head(training_size)
        d_train_data = d_data_all.head(training_size)
        print('Shape of Training Data {0}, Label {1}'.format(d_train_data.shape, d_train_labels.shape) )

        # standardize the data
        standardized_data = StandardScaler().fit_transform(d_train_data.astype(np.float64))
        standardized_data.shape
```

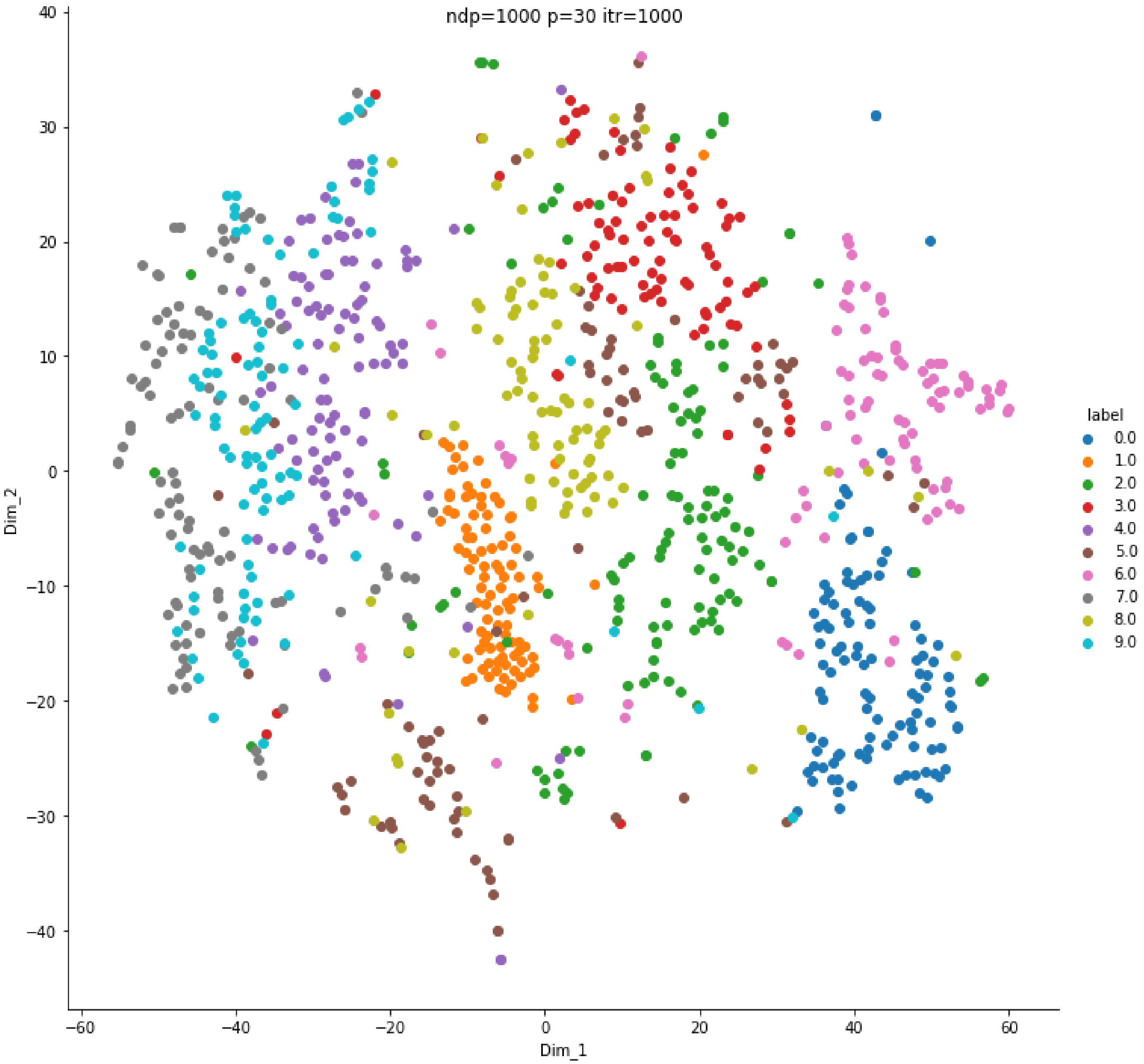
```
Shape of Training Data (15000, 784), Label (15000,)
```

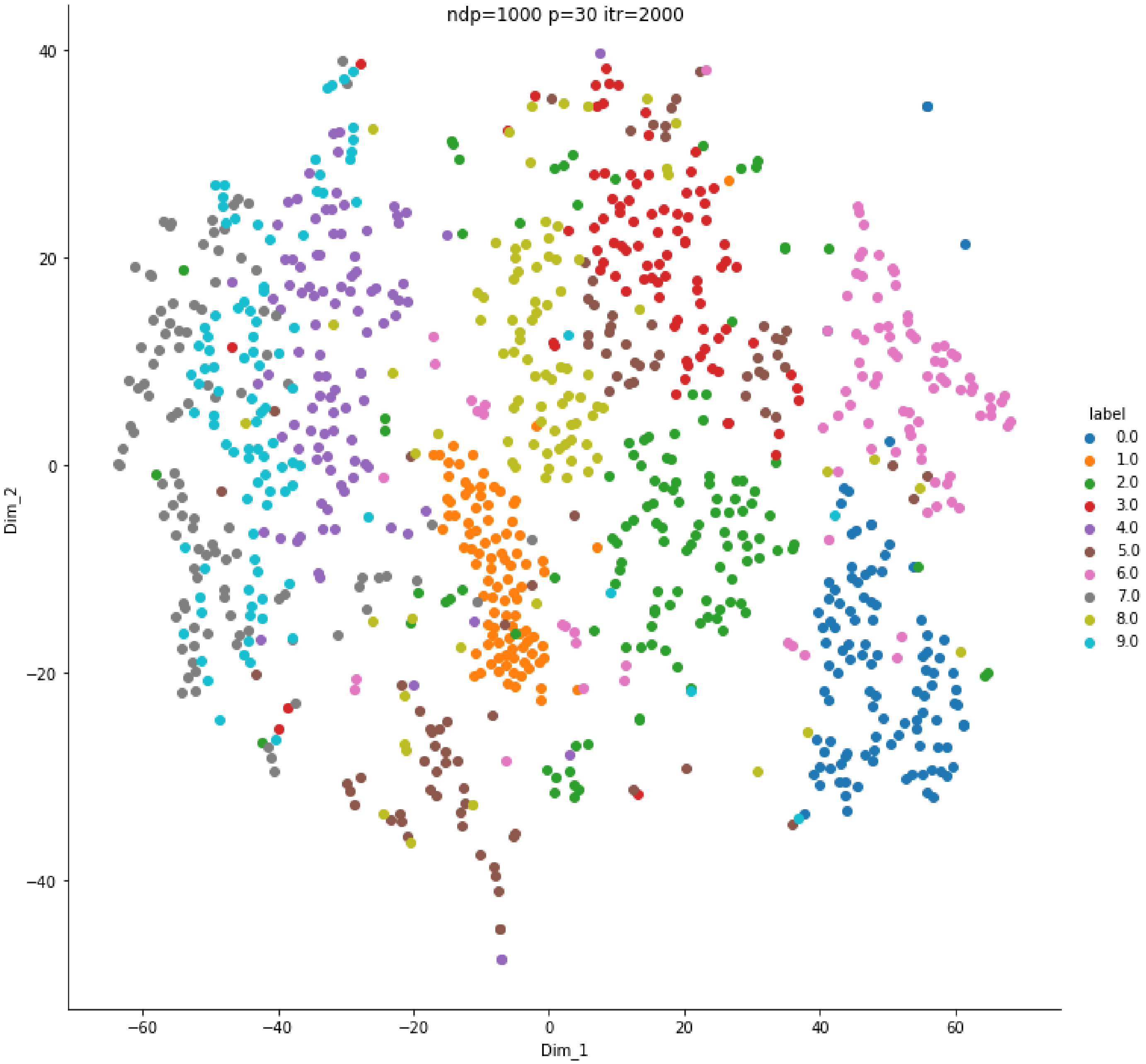
```
Out[ ]: (15000, 784)
```

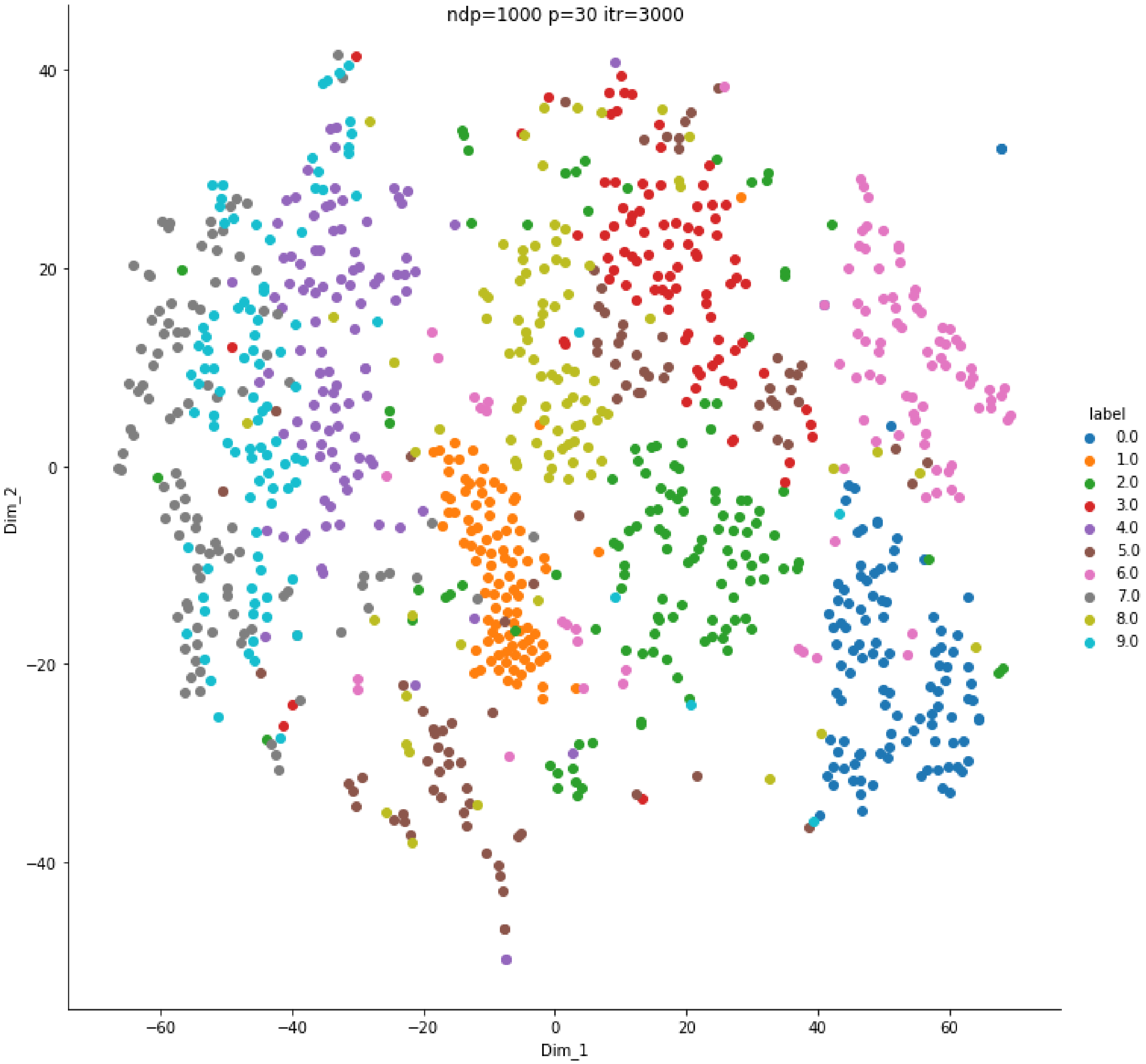
1.1.1 t-SNE over 1000 data points

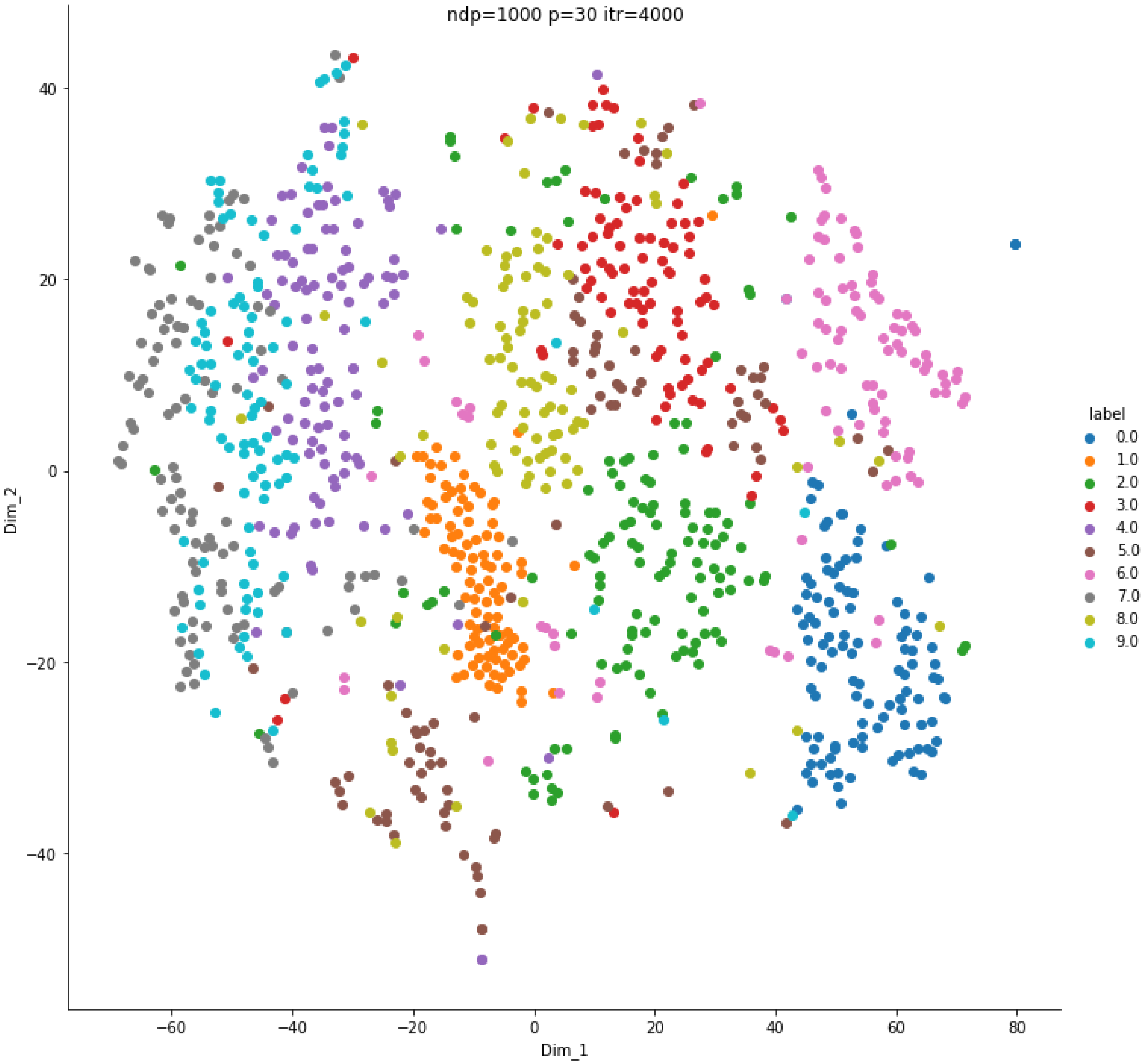
```
In [ ]: genTSNEGif(standardized_data, 1000, 30, range(1000,10001,1000), 't_15000_d_1000_p_30')
```

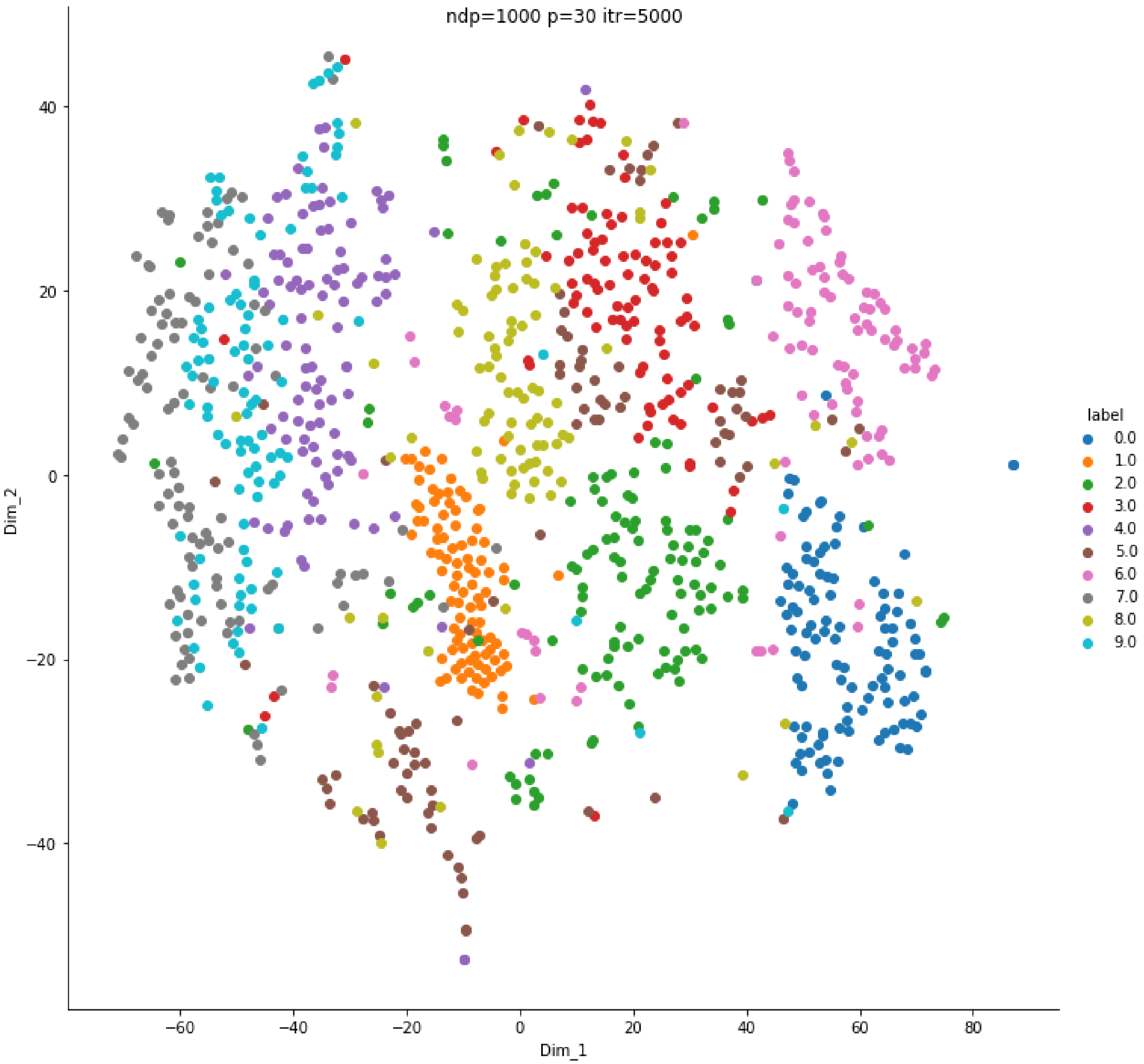
```
No.Of Data Points - 1000, Perplexity - 30, Iterations - range(1000, 10001, 1000), ImageName - t_15000_d_1000_p_30
ndp=1000 p=30 itr=1000 ==> t-SNE done! Time elapsed: 8.767564296722412 seconds
ndp=1000 p=30 itr=2000 ==> t-SNE done! Time elapsed: 15.281407833099365 seconds
ndp=1000 p=30 itr=3000 ==> t-SNE done! Time elapsed: 21.917317628860474 seconds
ndp=1000 p=30 itr=4000 ==> t-SNE done! Time elapsed: 28.54077696800232 seconds
ndp=1000 p=30 itr=5000 ==> t-SNE done! Time elapsed: 35.208890199661255 seconds
ndp=1000 p=30 itr=6000 ==> t-SNE done! Time elapsed: 42.100470781326294 seconds
ndp=1000 p=30 itr=7000 ==> t-SNE done! Time elapsed: 48.63226270675659 seconds
ndp=1000 p=30 itr=8000 ==> t-SNE done! Time elapsed: 55.15706443786621 seconds
ndp=1000 p=30 itr=9000 ==> t-SNE done! Time elapsed: 62.33098077774048 seconds
ndp=1000 p=30 itr=10000 ==> t-SNE done! Time elapsed: 65.65820598602295 seconds
```

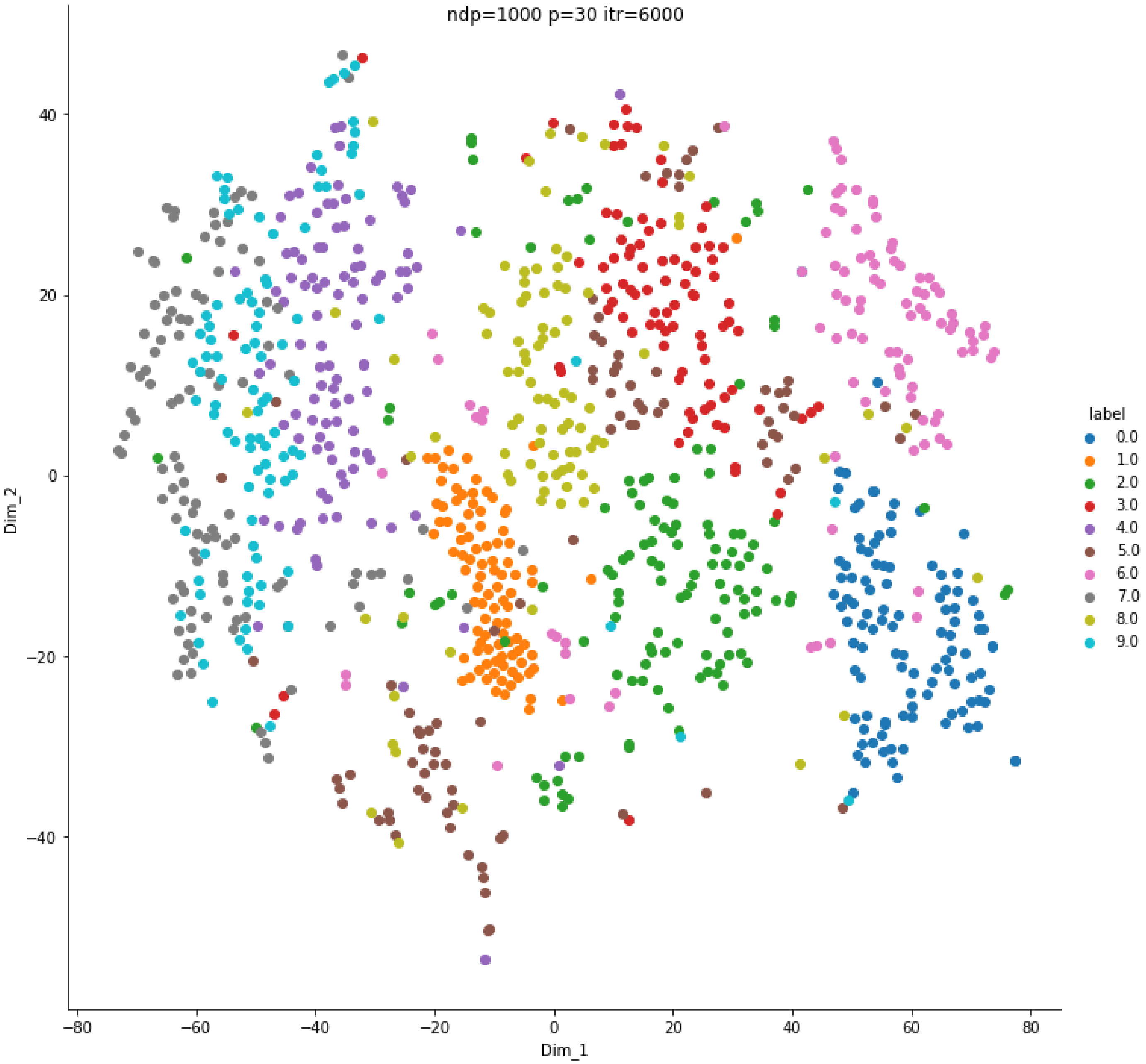

ndp=1000 p=30 itr=1000
Dim_2
Dim_1
40
30
20
10
0
−10
−20
−30
−40
−60
−40
−20
0
20
40
60
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0

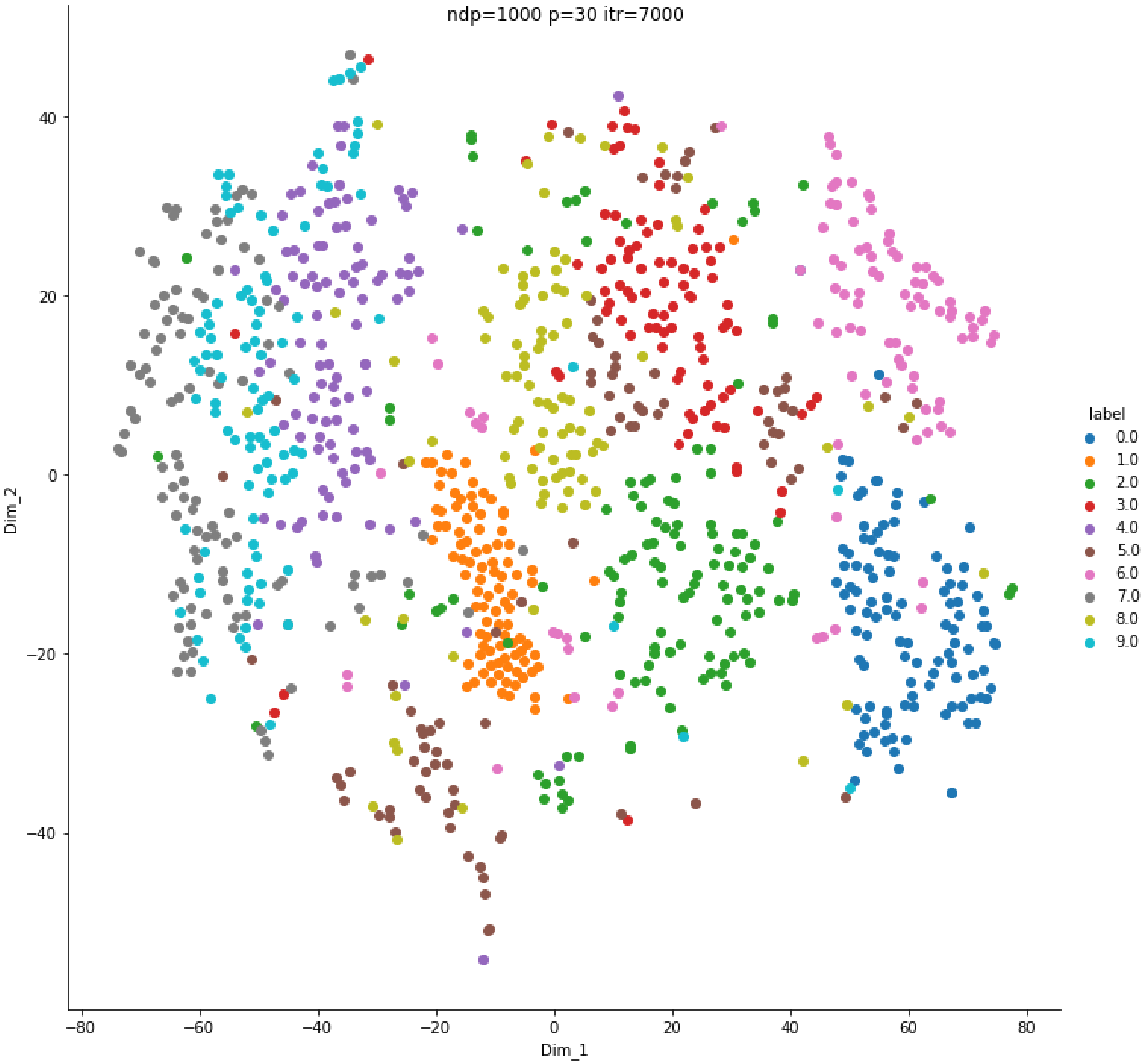

ndp=1000 p=30 itr=2000
40
20
0
−20
−40
Dim_2
−60
−40
−20
0
20
40
60
Dim_1
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0

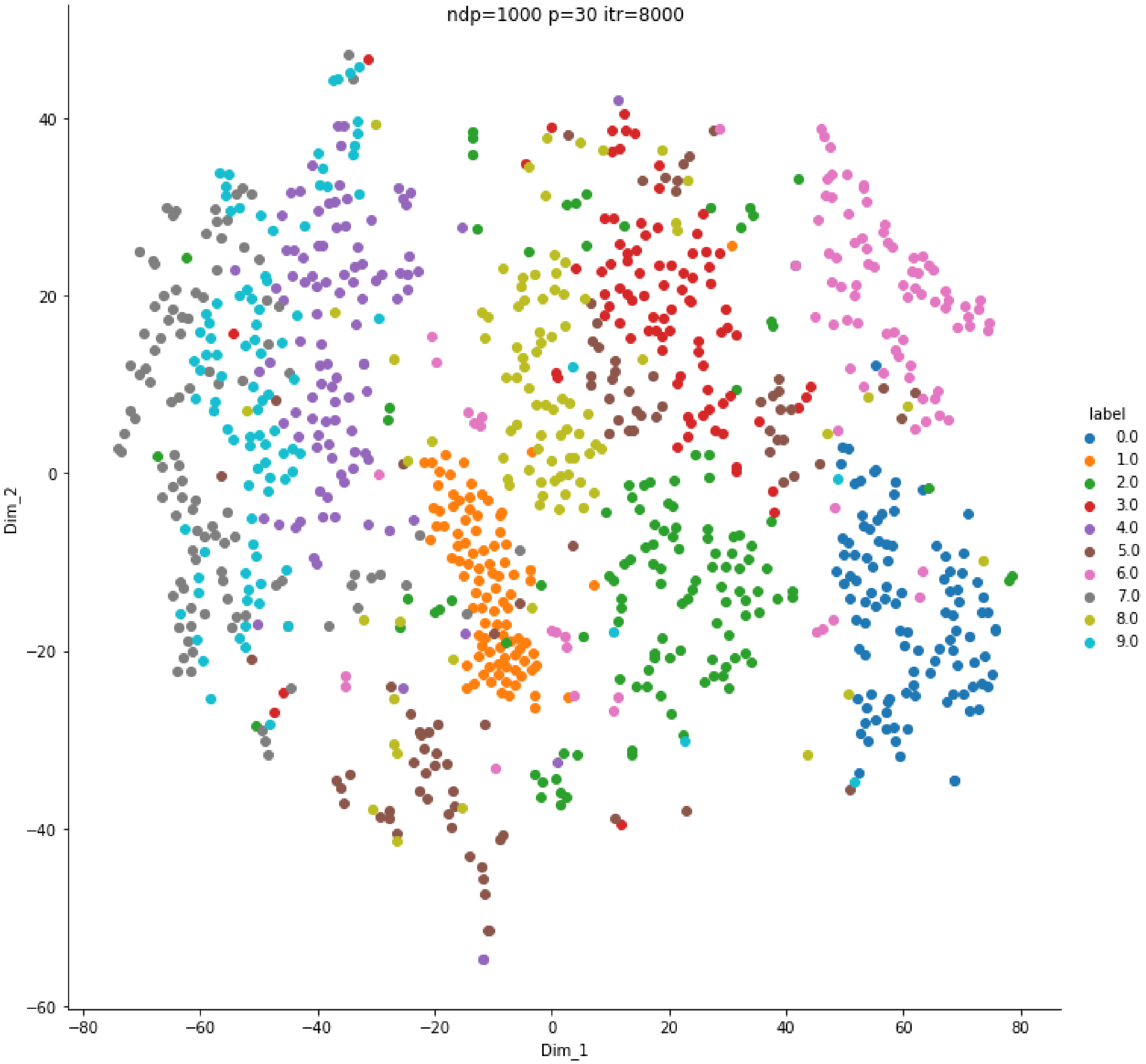

ndp=1000 p=30 itr=3000
Dim_2
Dim_1
40
20
0
−20
−40
−60
−40
−20
0
20
40
60
label
● 0.0
● 1.0
● 2.0
● 3.0
● 4.0
● 5.0
● 6.0
● 7.0
● 8.0
● 9.0

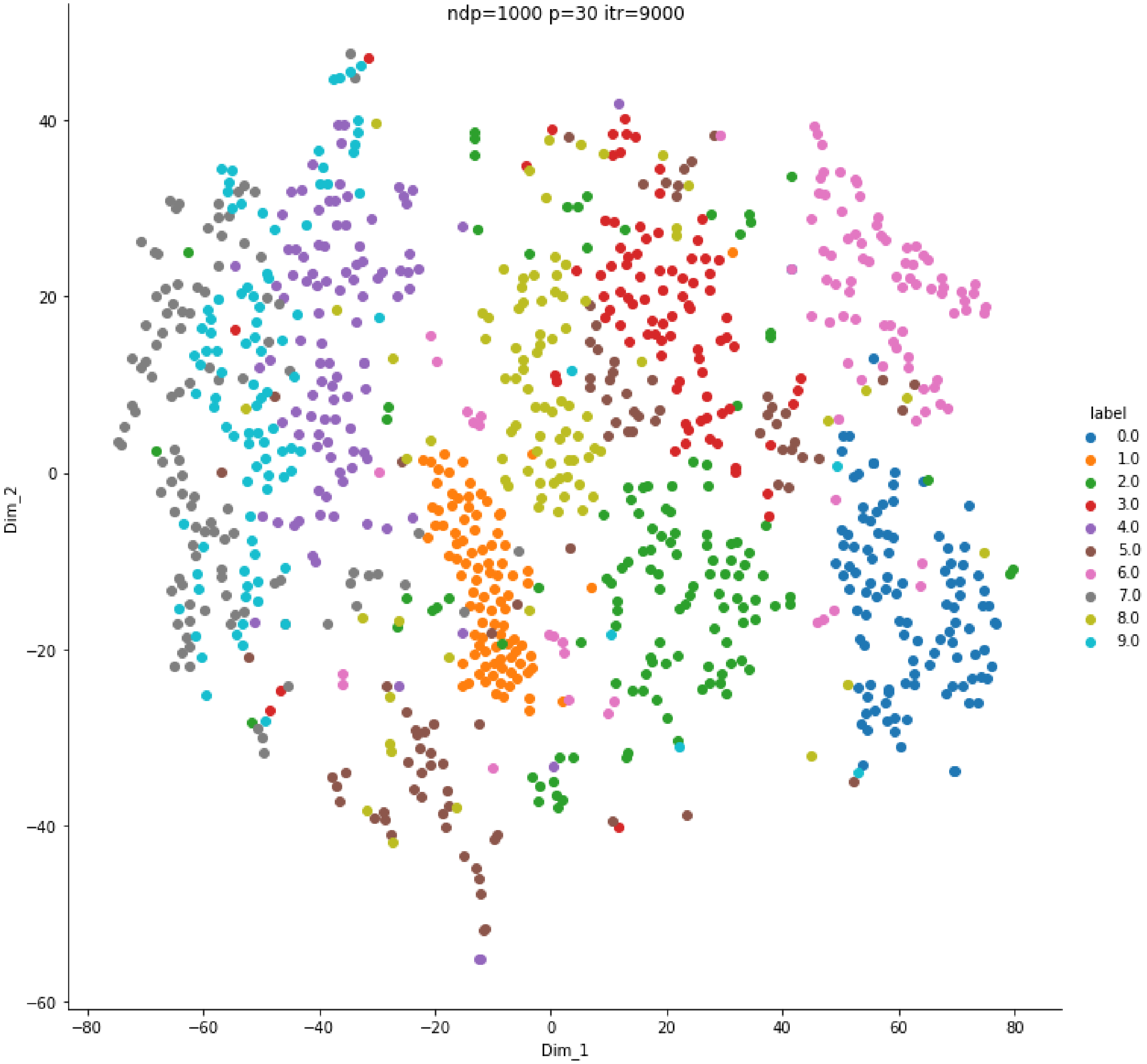

ndp=1000 p=30 itr=4000
Dim_2
Dim_1
40
20
0
−20
−40
−60
−40
−20
0
20
40
60
80
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0

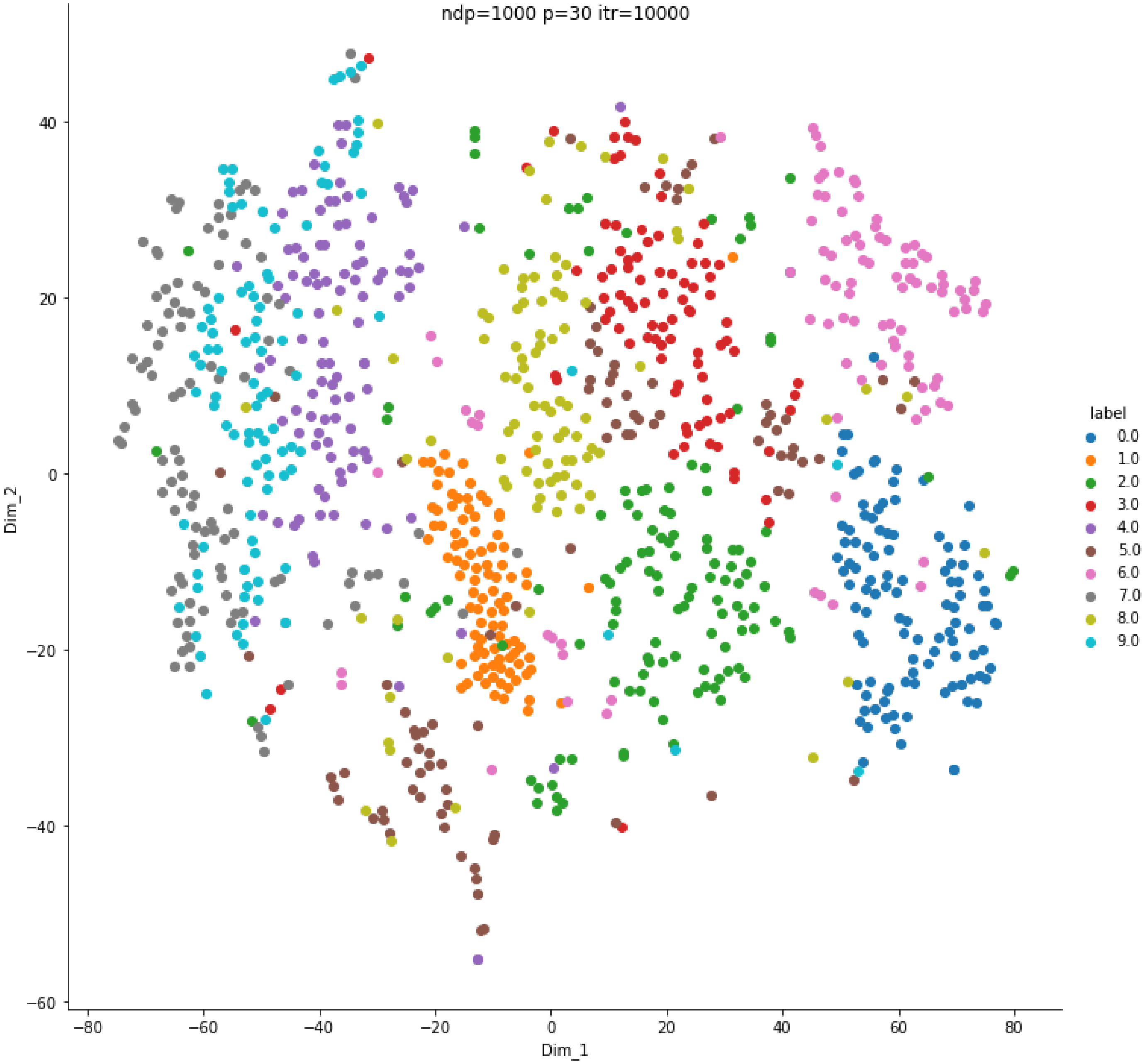

ndp=1000 p=30 itr=5000
Dim_2
Dim_1
40
20
0
−20
−40
−60
−40
−20
0
20
40
60
80
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0


ndp=1000 p=30 itr=6000
Dim_2
40
20
0
−20
−40
−80
−60
−40
−20
0
20
40
60
80
Dim_1
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0


ndp=1000 p=30 itr=7000
Dim_2
40
20
0
−20
−40
Dim_1
−80
−60
−40
−20
0
20
40
60
80
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0

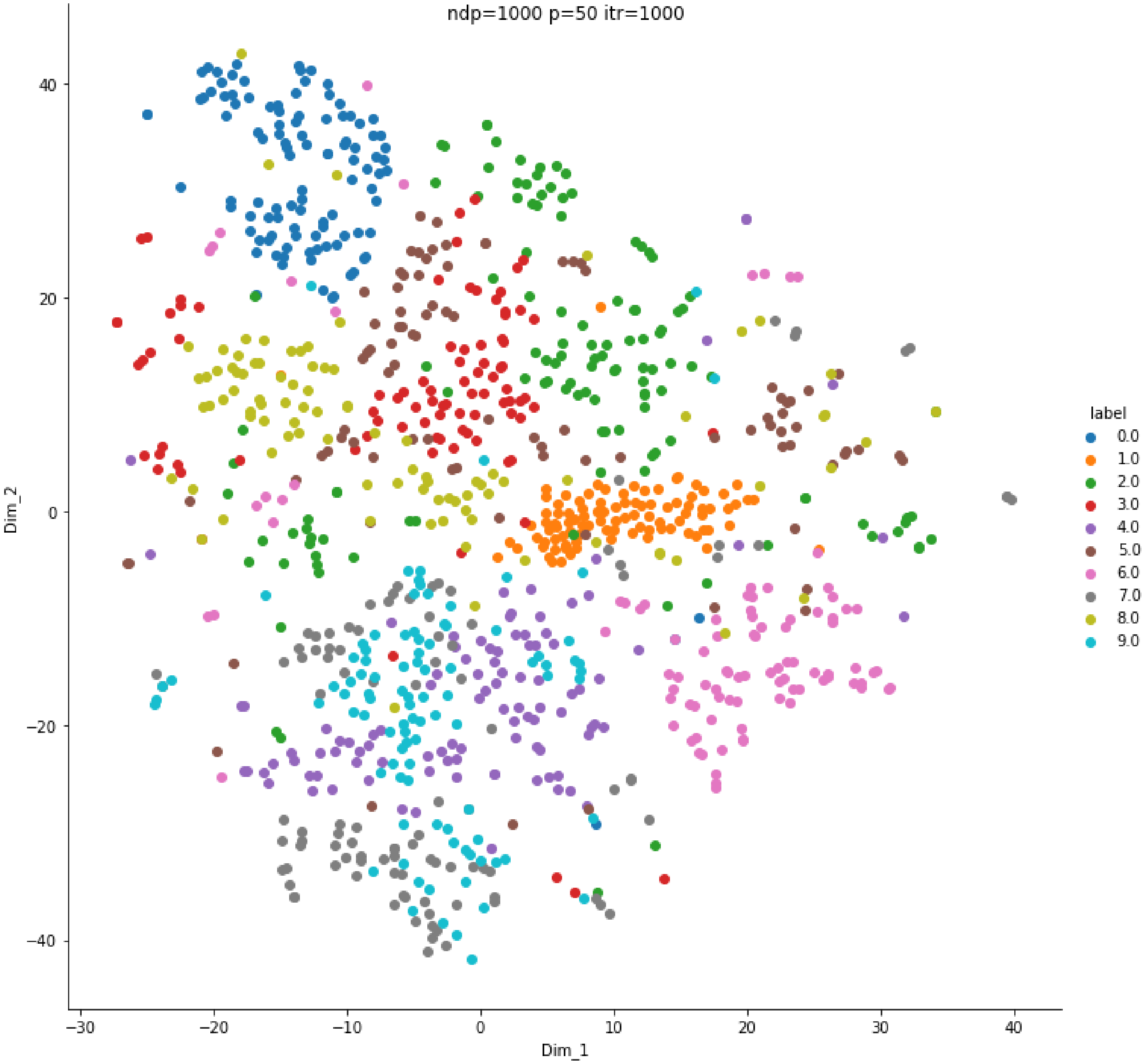

ndp=1000 p=30 itr=8000
Dim_2
Dim_1
40
20
0
−20
−40
−60
−80
−60
−40
−20
0
20
40
60
80
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0

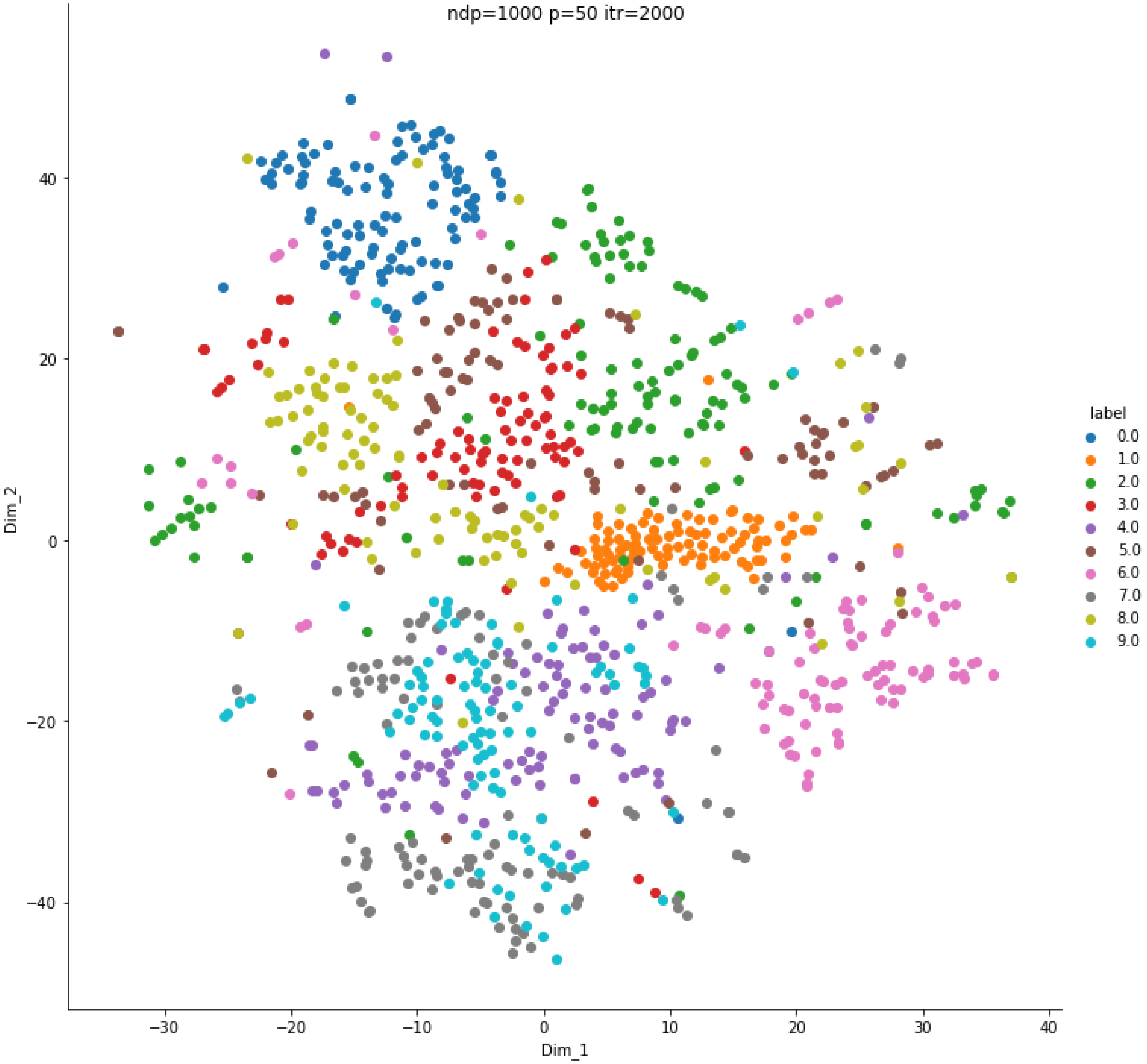

ndp=1000 p=30 itr=9000
Dim_2
Dim_1
40
20
0
−20
−40
−60
−80
−60
−40
−20
0
20
40
60
80
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0

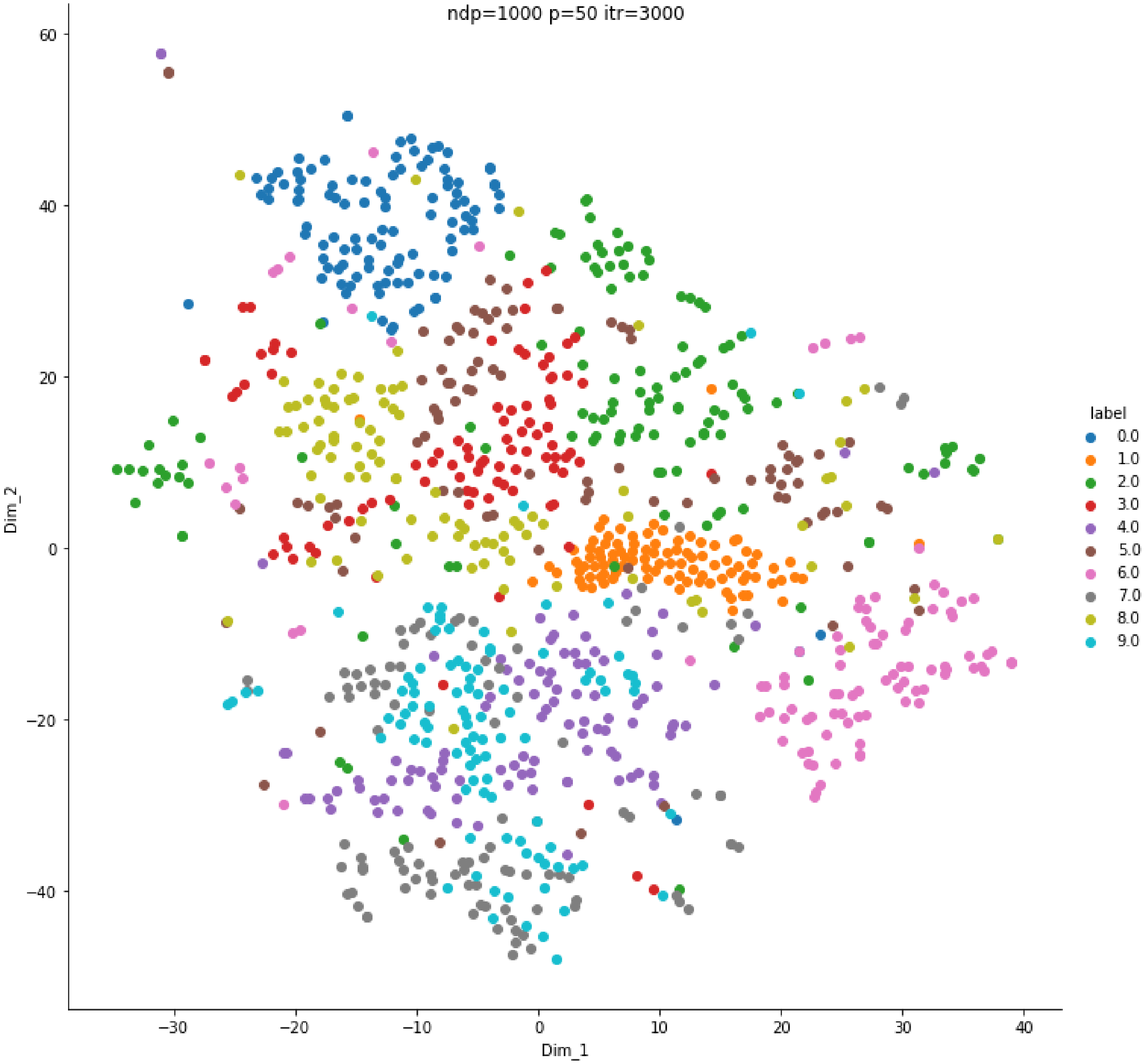


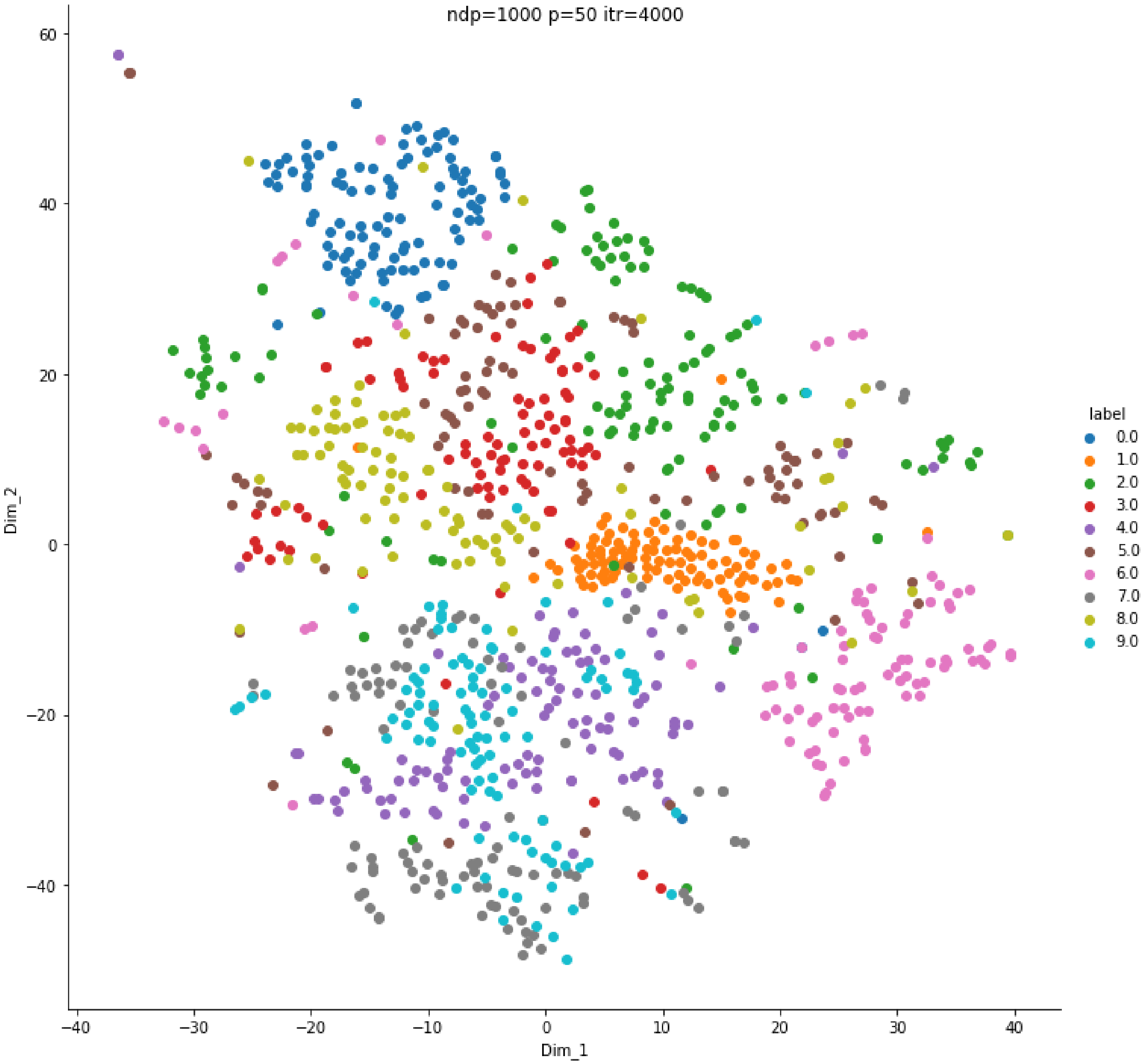
```
In [ ]: genTSNEGif(standardized_data, 1000, 50, range(1000,10001,1000), 't_15000_d_1000_p_50')
```

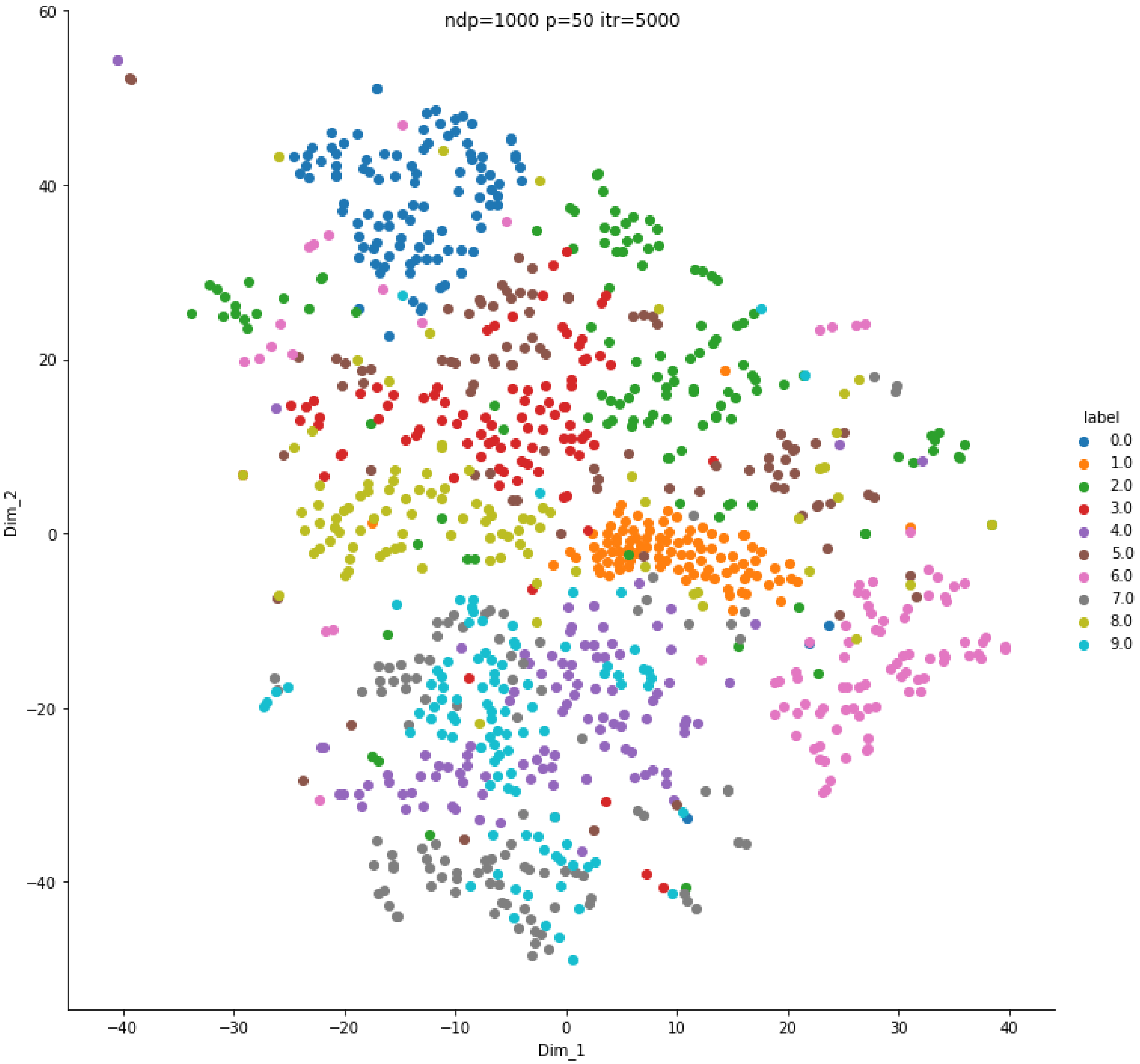
```
No.Of Data Points - 1000, Perplexity - 50, Iterations - range(1000, 10001, 1000), ImageName - t_15000_d_1000_p_50
ndp=1000 p=50 itr=1000 ==> t-SNE done! Time elapsed: 10.508925676345825 seconds
ndp=1000 p=50 itr=2000 ==> t-SNE done! Time elapsed: 19.109923362731934 seconds
ndp=1000 p=50 itr=3000 ==> t-SNE done! Time elapsed: 26.708609580993652 seconds
ndp=1000 p=50 itr=4000 ==> t-SNE done! Time elapsed: 33.94826126098633 seconds
ndp=1000 p=50 itr=5000 ==> t-SNE done! Time elapsed: 41.6116144657135 seconds
ndp=1000 p=50 itr=6000 ==> t-SNE done! Time elapsed: 48.758673429489136 seconds
ndp=1000 p=50 itr=7000 ==> t-SNE done! Time elapsed: 51.300100326538086 seconds
ndp=1000 p=50 itr=8000 ==> t-SNE done! Time elapsed: 50.943241357803345 seconds
ndp=1000 p=50 itr=9000 ==> t-SNE done! Time elapsed: 51.112380266189575 seconds
ndp=1000 p=50 itr=10000 ==> t-SNE done! Time elapsed: 51.14729022979736 seconds
```

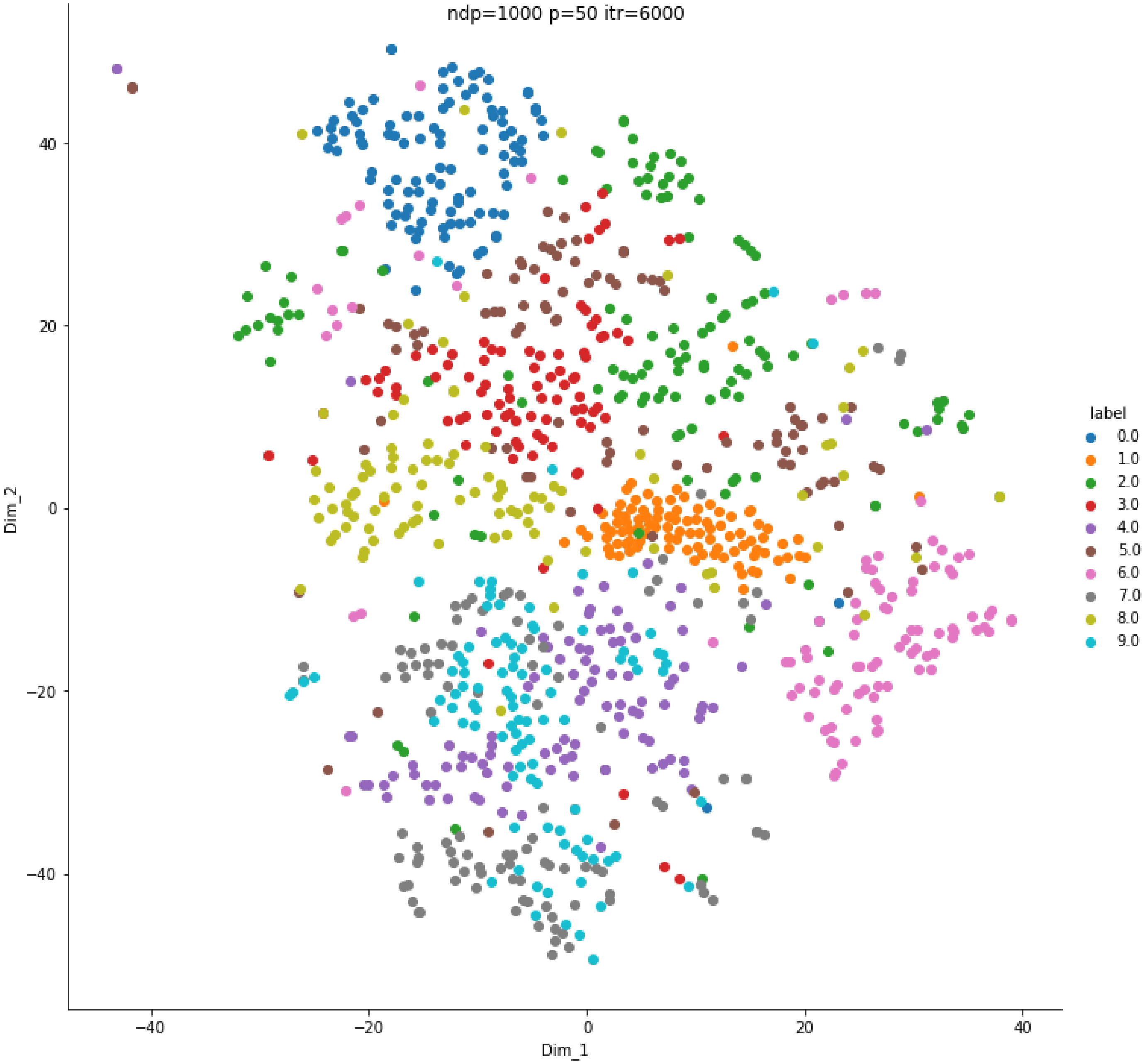

ndp=1000 p=50 itr=1000
Dim_2
Dim_1
40
20
0
−20
−40
−30
−20
−10
0
10
20
30
40
label
● 0.0
● 1.0
● 2.0
● 3.0
● 4.0
● 5.0
● 6.0
● 7.0
● 8.0
● 9.0

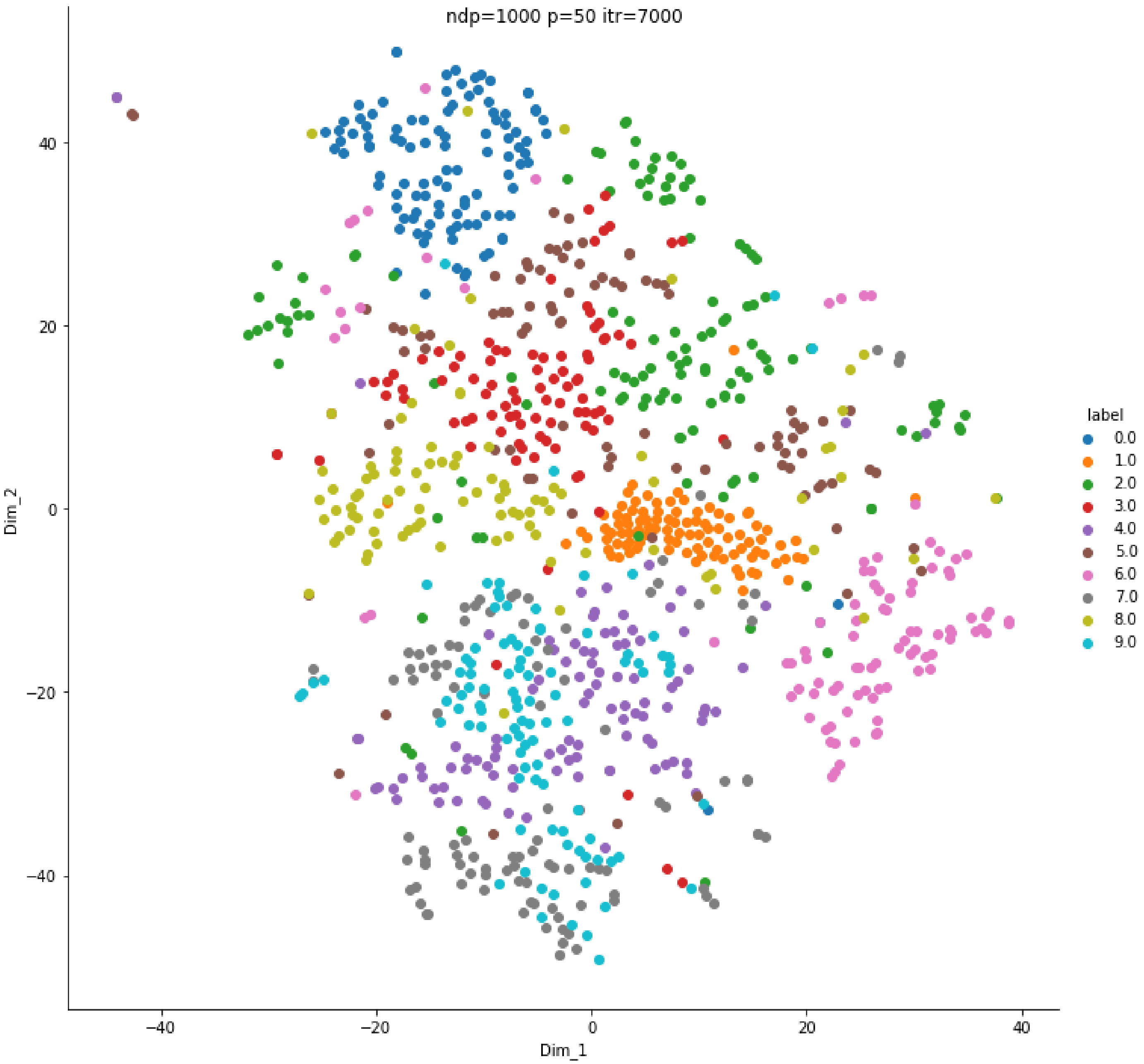

ndp=1000 p=50 itr=2000
Dim_2
Dim_1
40
20
0
−20
−40
−30
−20
−10
0
10
20
30
40
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0

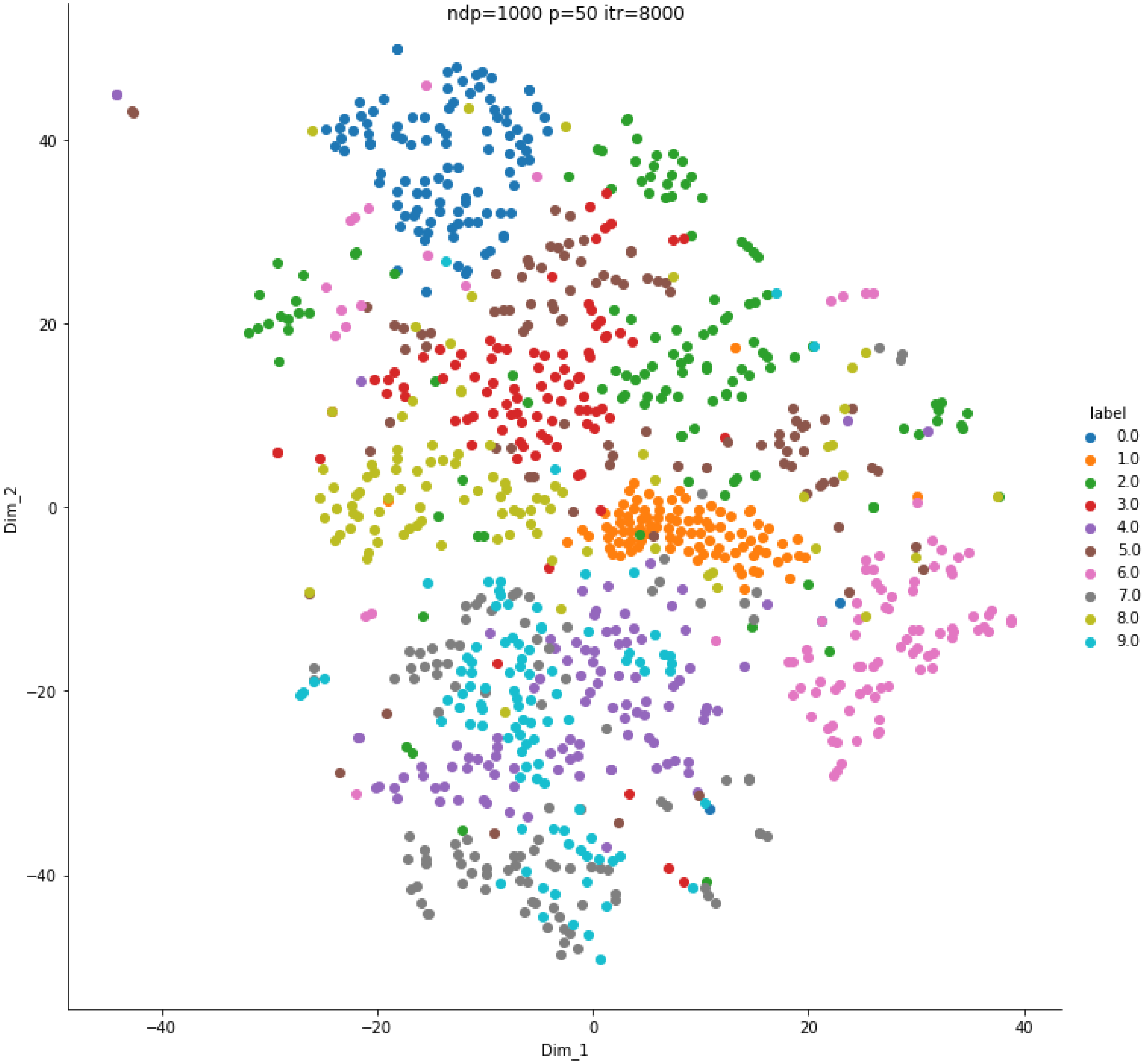

ndp=1000 p=50 itr=3000
Dim_2
60
40
20
0
−20
−40
Dim_1
−30
−20
−10
0
10
20
30
40
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0

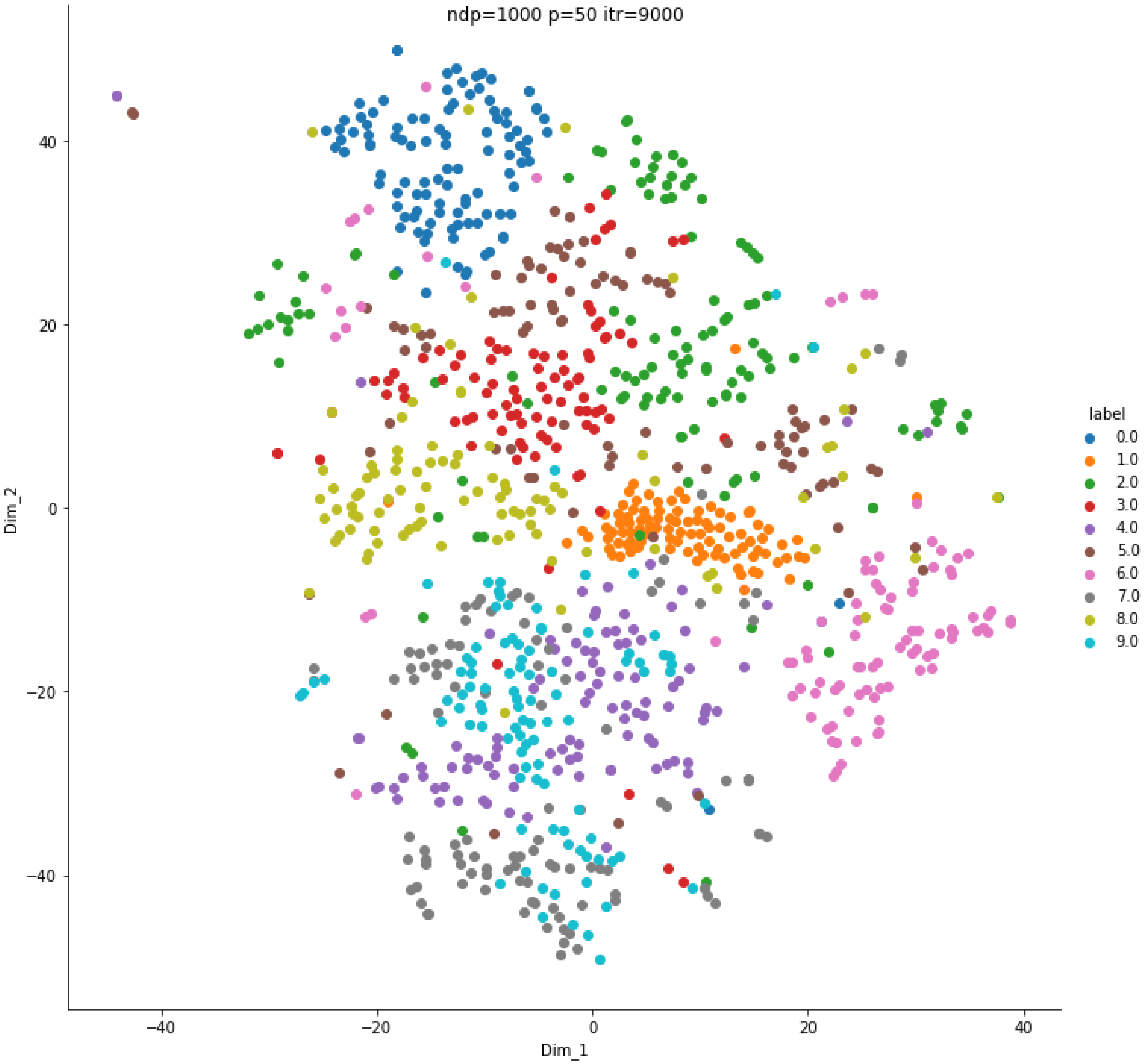

ndp=1000 p=50 itr=4000
Dim_2
60
40
20
0
−20
−40
Dim_1
−40
−30
−20
−10
0
10
20
30
40
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0

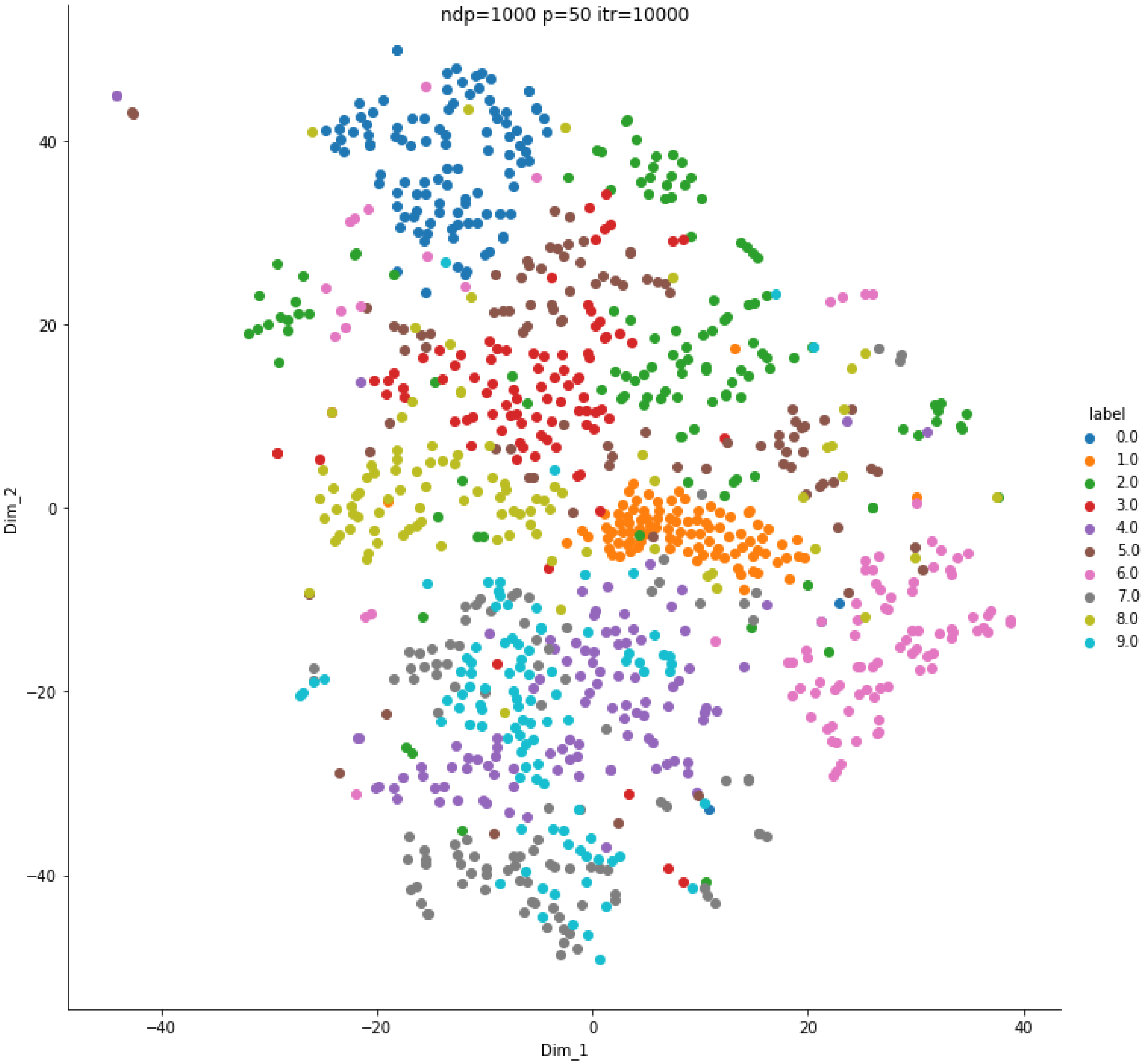

ndp=1000 p=50 itr=5000
Dim_2
Dim_1
60
40
20
0
−20
−40
−40
−30
−20
−10
0
10
20
30
40
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0


ndp=1000 p=50 itr=6000
Dim_2
40
20
0
−20
−40
Dim_1
−40
−20
0
20
40
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0


ndp=1000 p=50 itr=7000
Dim_2
Dim_1
40
20
0
−20
−40
−40
−20
0
20
40
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0


ndp=1000 p=50 itr=8000
Dim_2
Dim_1
40
20
0
−20
−40
−40
−20
0
20
40
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0

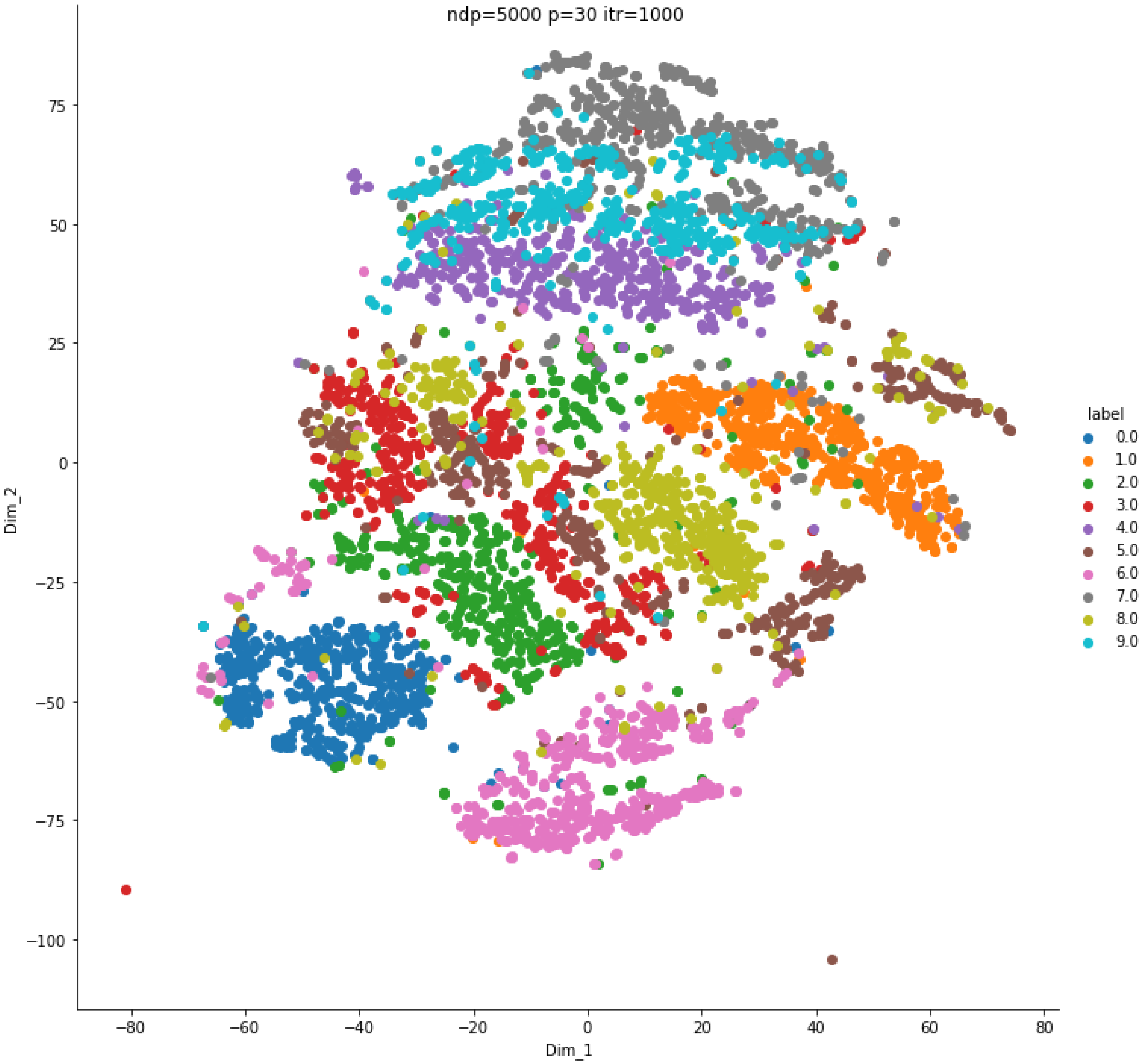

ndp=1000 p=50 itr=9000
Dim_2
40
20
0
−20
−40
Dim_1
−40
−20
0
20
40
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0

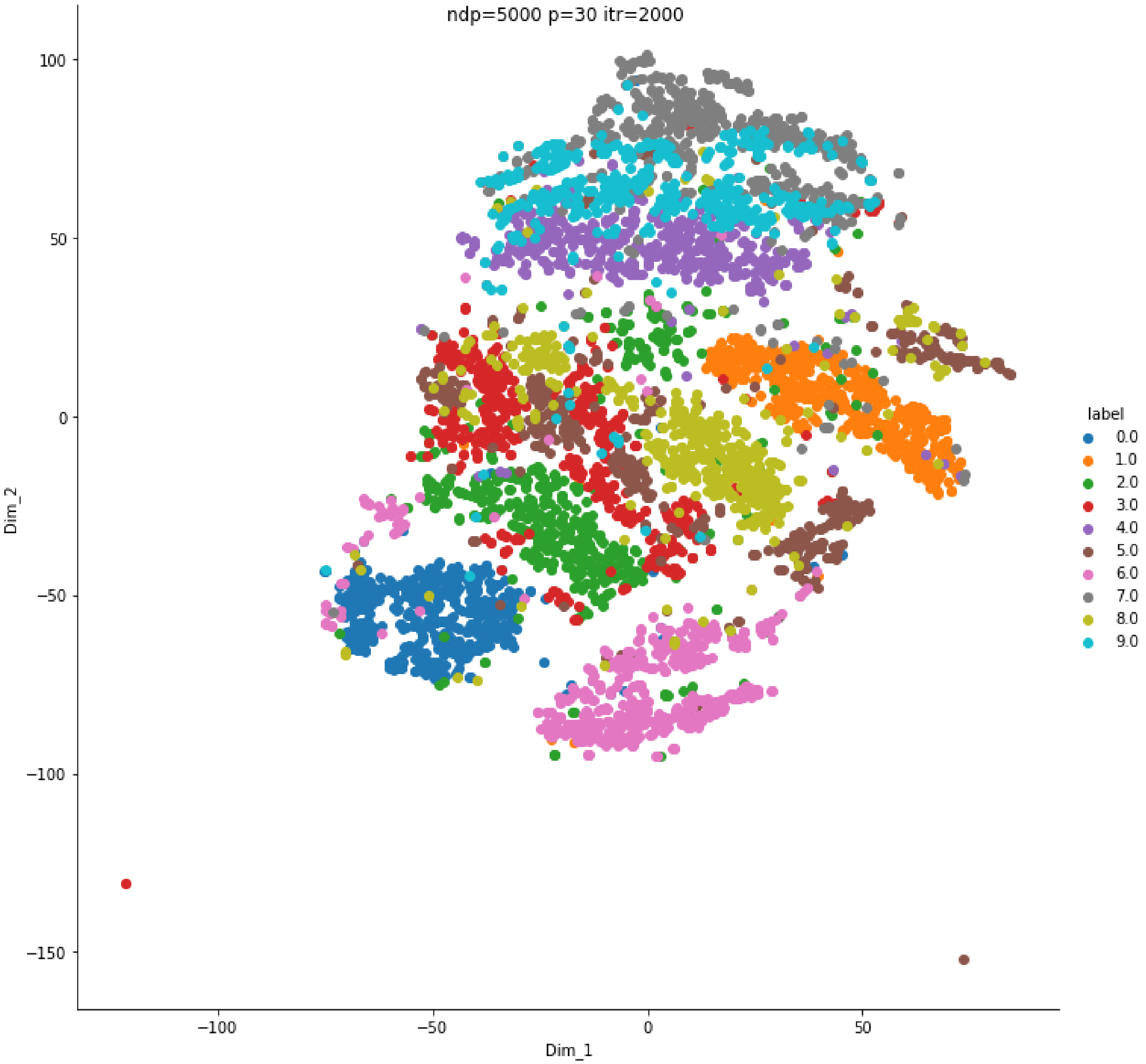


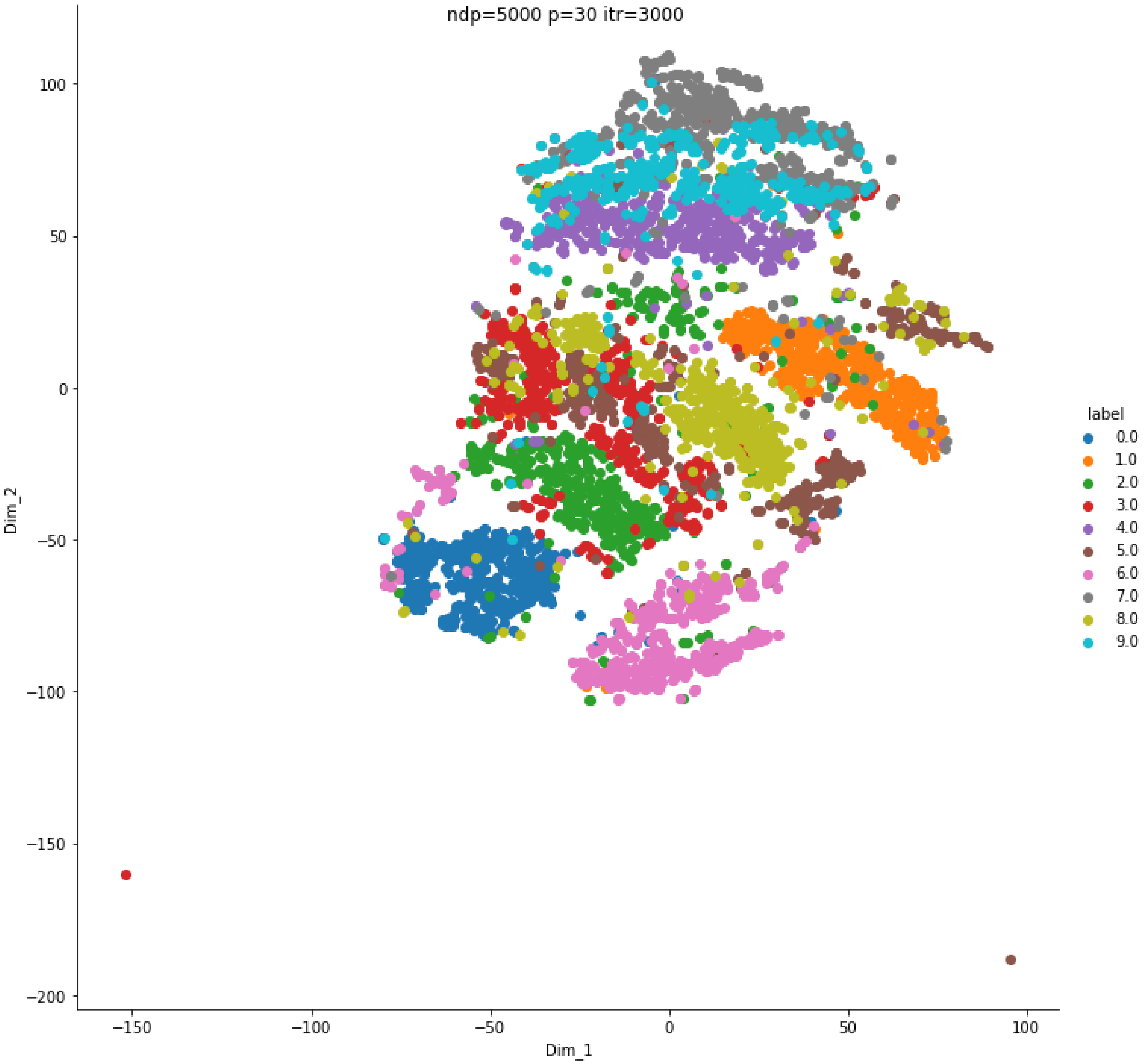
1.1.2 t-SNE over 5000 data points

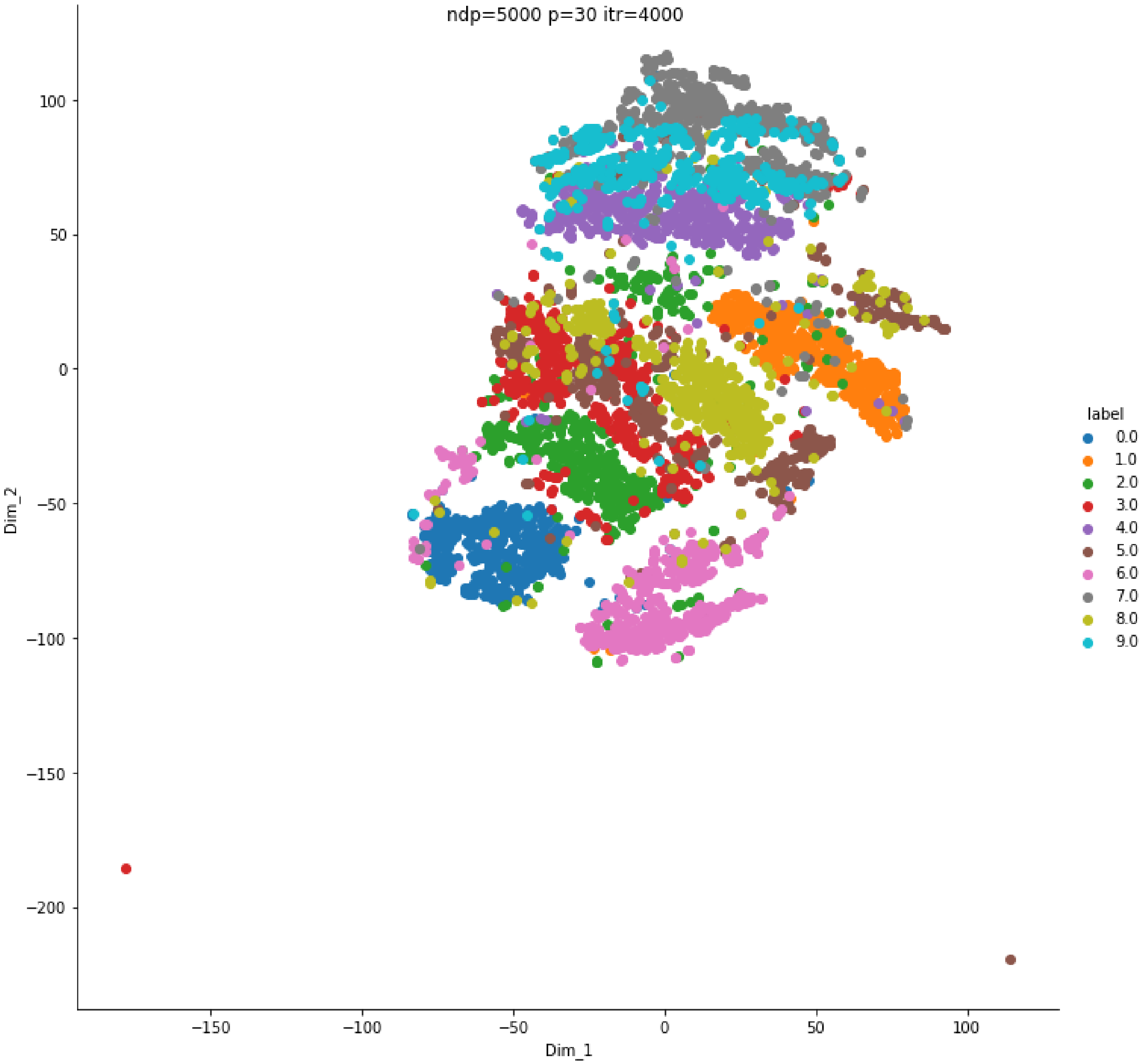
```
In [ ]: genTSNEGif(standardized_data, 5000, 30, range(1000,10001,1000), 't_15000_d_5000_p_30')
```

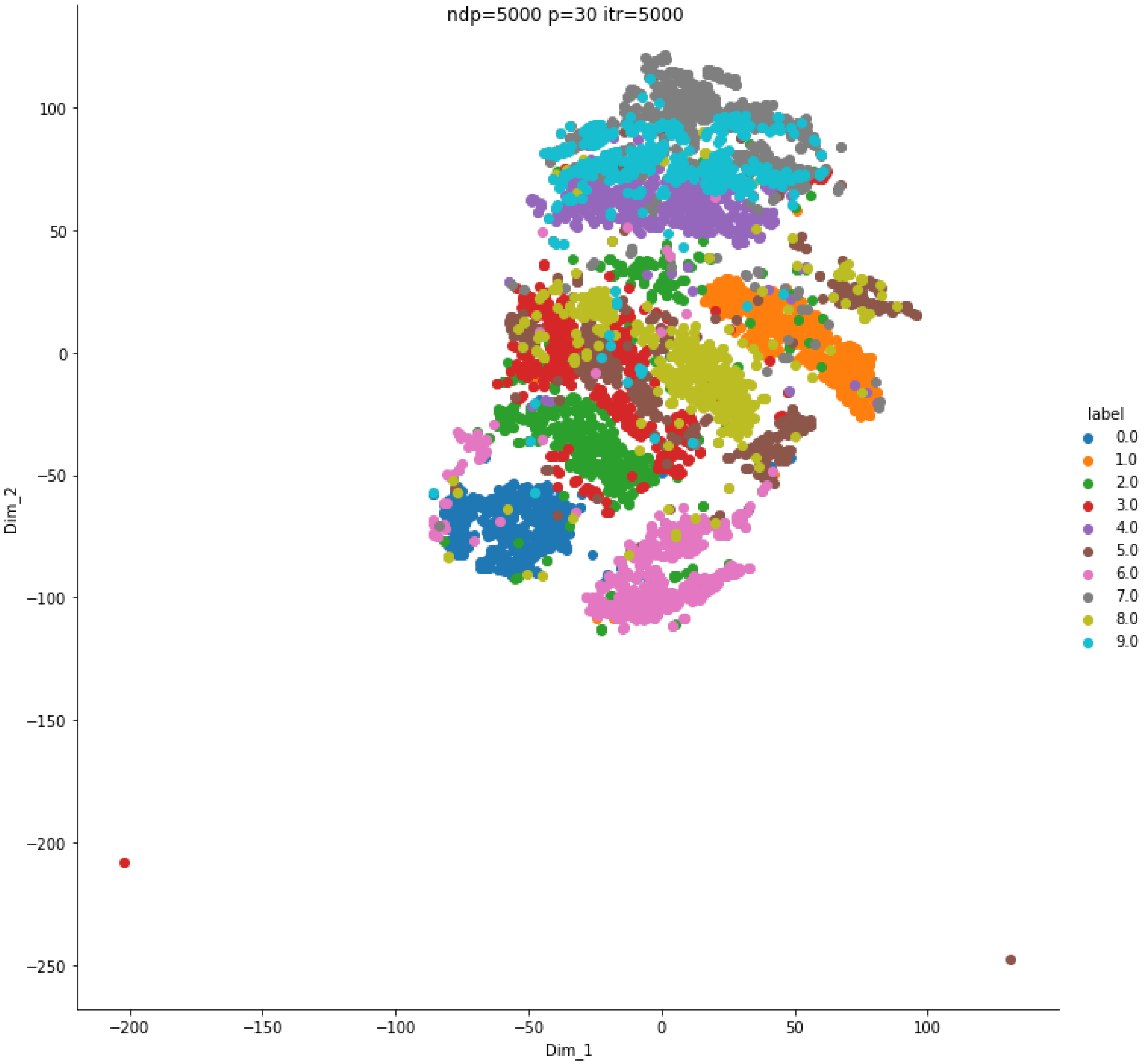
```
No.Of Data Points - 5000, Perplexity - 30, Iterations - range(1000, 10001, 1000), ImageName - t_15000_d_5000_p_30
ndp=5000 p=30 itr=1000 ==> t-SNE done! Time elapsed: 74.58964729309082 seconds
ndp=5000 p=30 itr=2000 ==> t-SNE done! Time elapsed: 116.96771430969238 seconds
ndp=5000 p=30 itr=3000 ==> t-SNE done! Time elapsed: 158.1489634513855 seconds
ndp=5000 p=30 itr=4000 ==> t-SNE done! Time elapsed: 199.8348081111908 seconds
ndp=5000 p=30 itr=5000 ==> t-SNE done! Time elapsed: 239.5248773097992 seconds
ndp=5000 p=30 itr=6000 ==> t-SNE done! Time elapsed: 281.1372809410095 seconds
ndp=5000 p=30 itr=7000 ==> t-SNE done! Time elapsed: 319.49059796333313 seconds
ndp=5000 p=30 itr=8000 ==> t-SNE done! Time elapsed: 355.5566313266754 seconds
ndp=5000 p=30 itr=9000 ==> t-SNE done! Time elapsed: 391.9184534549713 seconds
ndp=5000 p=30 itr=10000 ==> t-SNE done! Time elapsed: 427.03921484947205 seconds
```

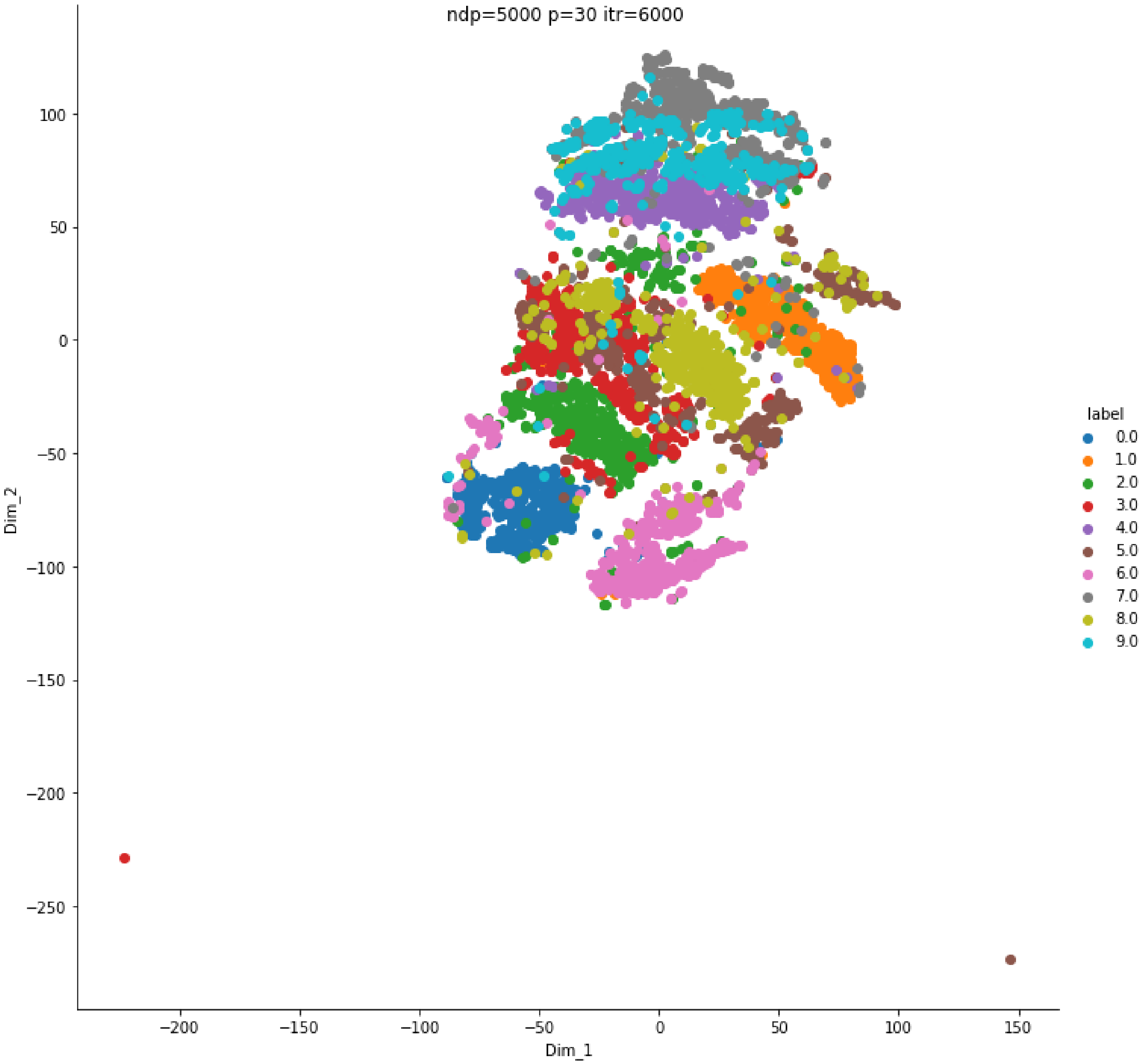

ndp=5000 p=30 itr=1000
75
50
25
0
−25
−50
−75
−100
Dim_2
−80
−60
−40
−20
0
20
40
60
80
Dim_1
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0

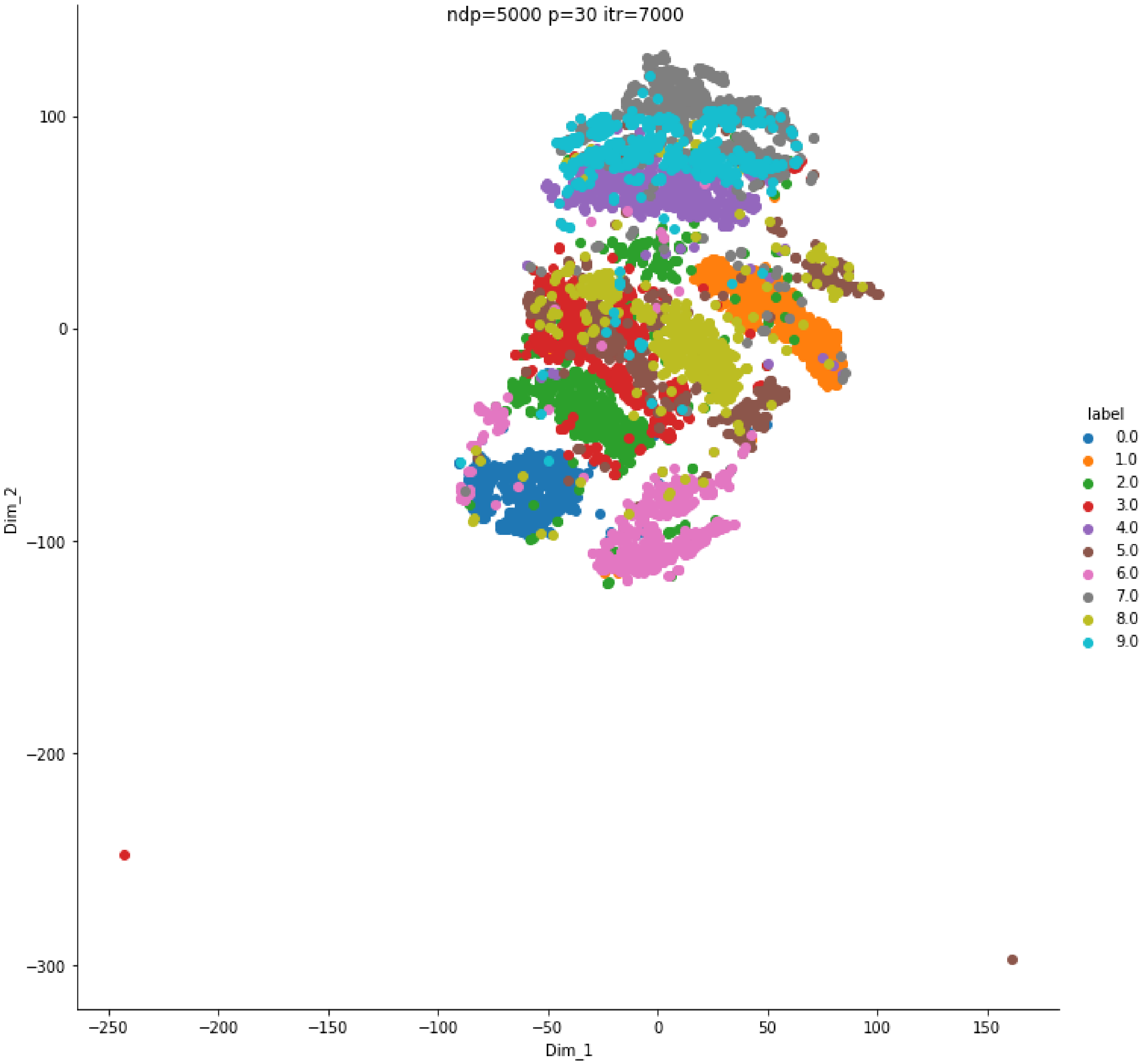

ndp=5000 p=30 itr=2000
100
50
0
−50
−100
−150
Dim_2
−100
−50
0
50
Dim_1
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0

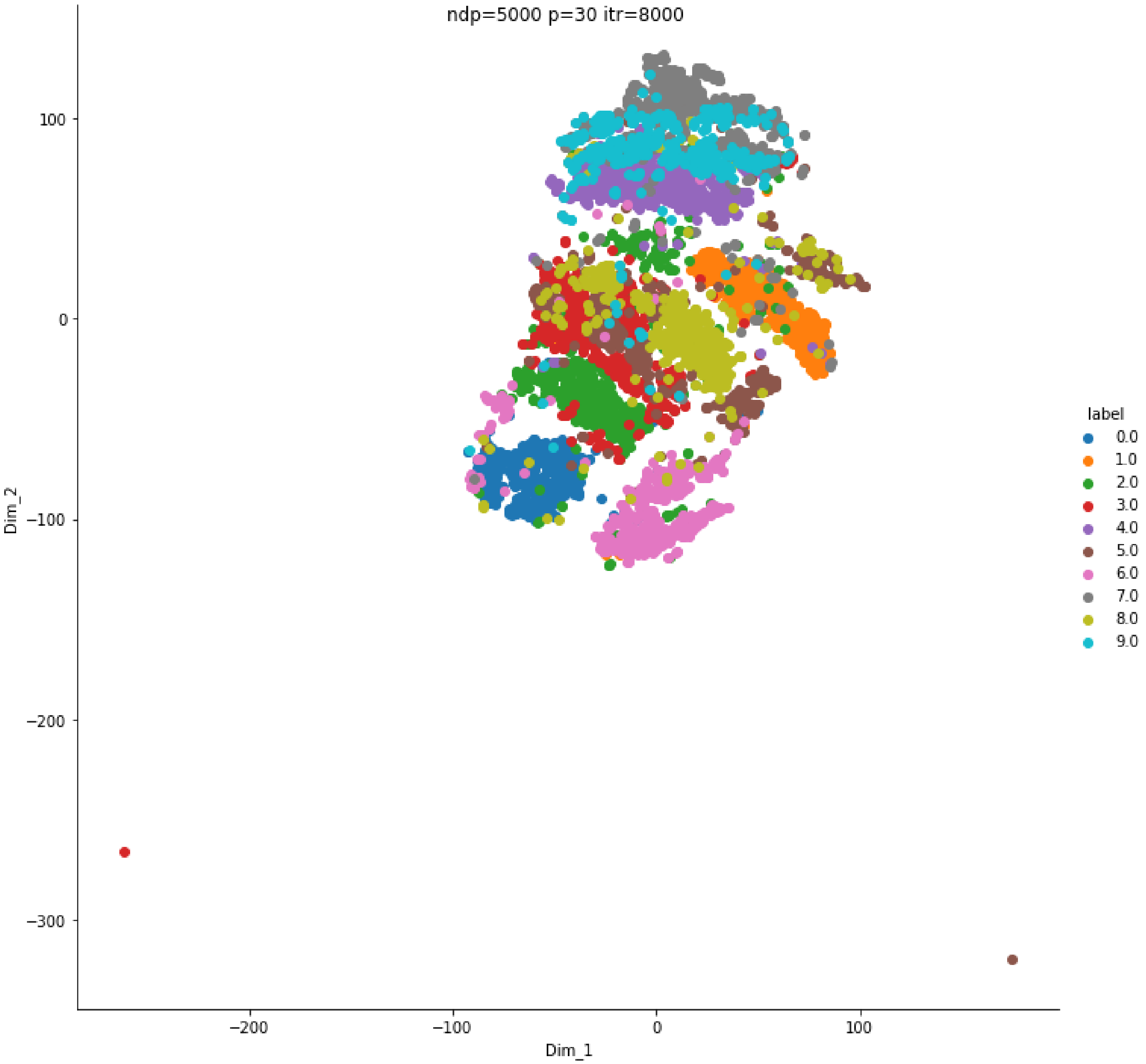

ndp=5000 p=30 itr=3000
100
50
0
−50
−100
−150
−200
Dim_2
−150
−100
−50
0
50
100
Dim_1
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0

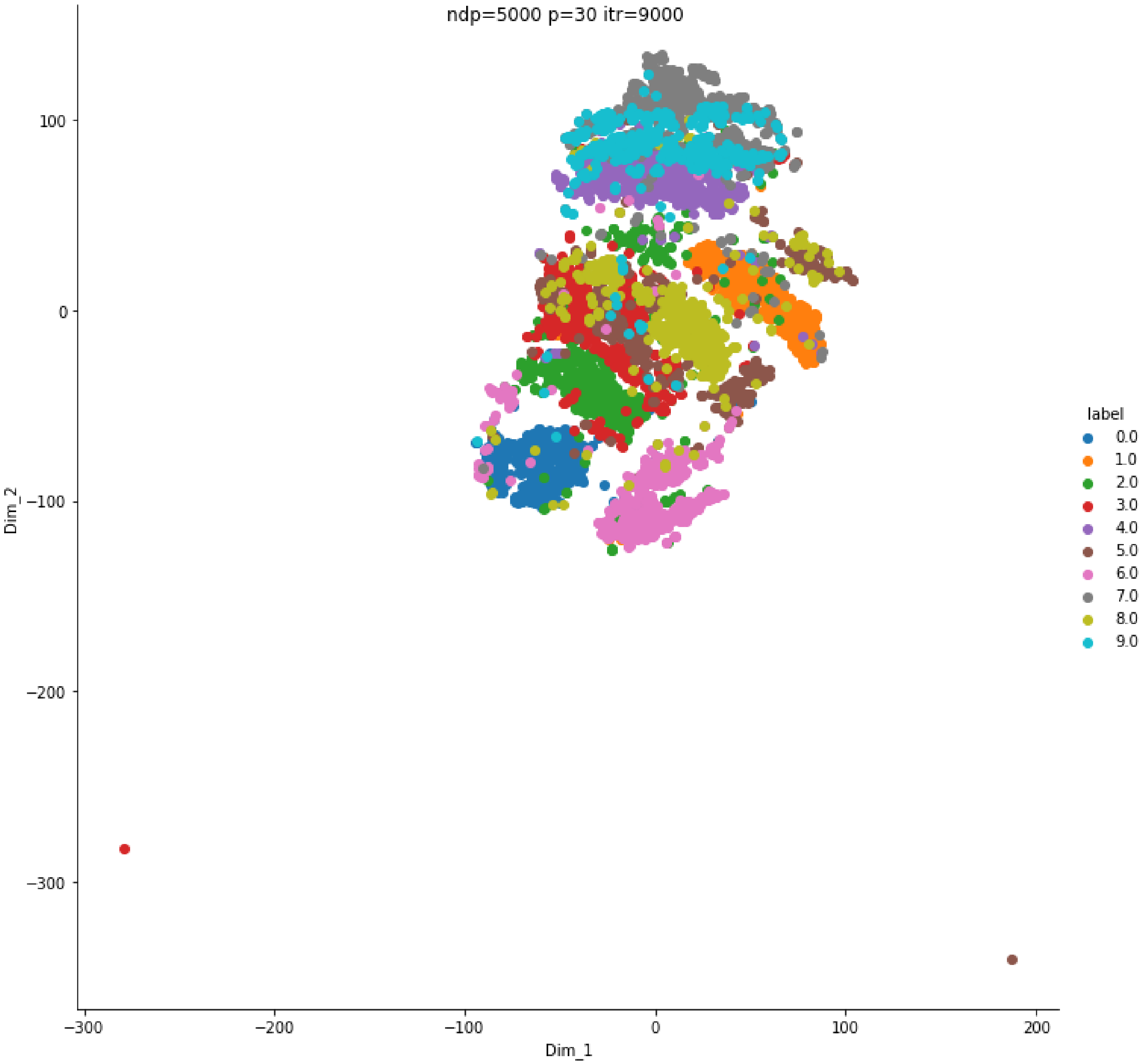

ndp=5000 p=30 itr=4000
100
50
0
−50
−100
−150
−200
Dim_2
−150
−100
−50
0
50
100
Dim_1
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0

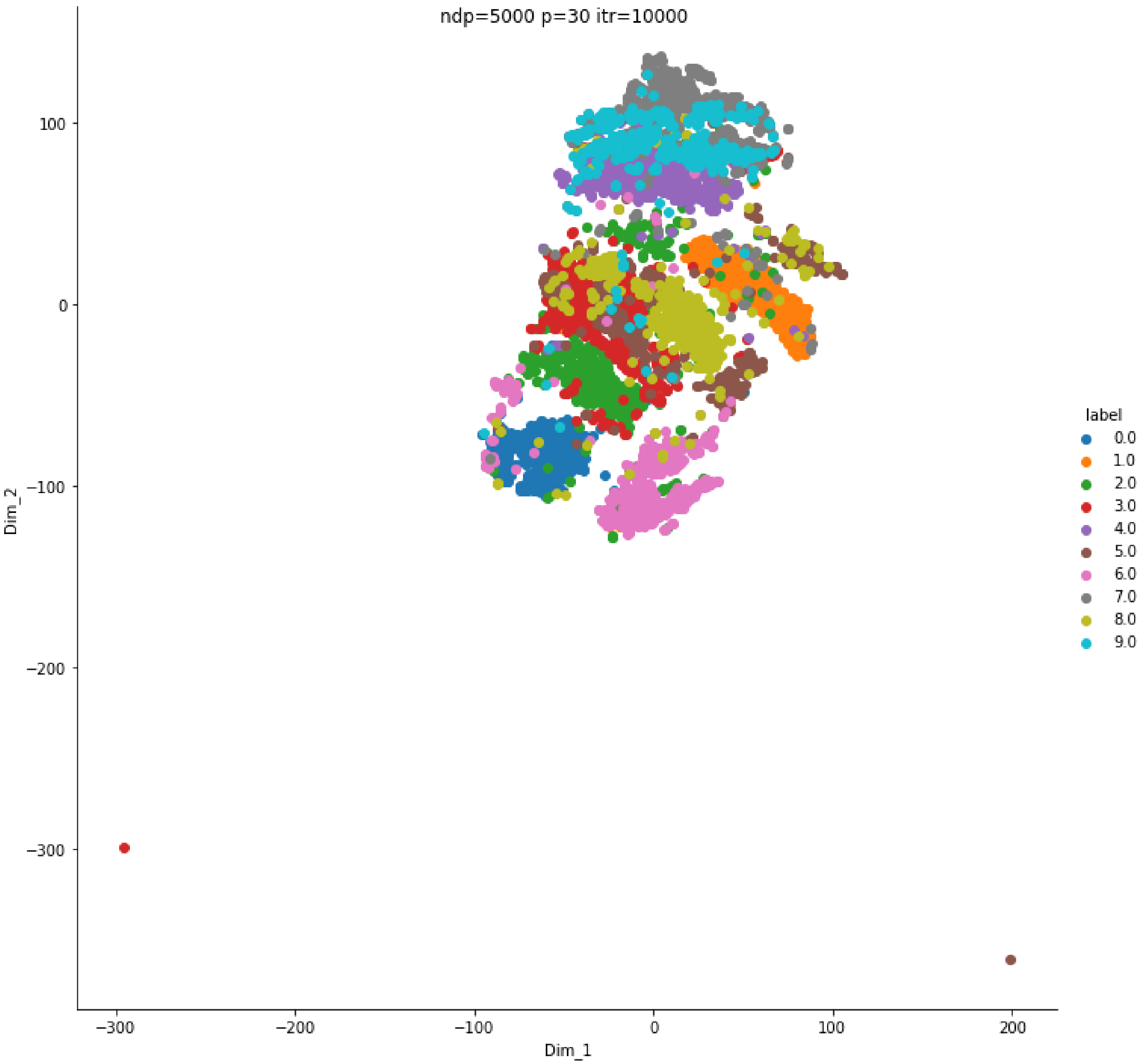

ndp=5000 p=30 itr=5000
Dim_2
Dim_1
100
50
0
−50
−100
−150
−200
−250
−200
−150
−100
−50
0
50
100
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0


ndp=5000 p=30 itr=6000
Dim_2
Dim_1
100
50
0
−50
−100
−150
−200
−250
−200
−150
−100
−50
0
50
100
150
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0


ndp=5000 p=30 itr=7000
Dim_2
Dim_1
100
0
−100
−200
−300
−250
−200
−150
−100
−50
0
50
100
150
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0

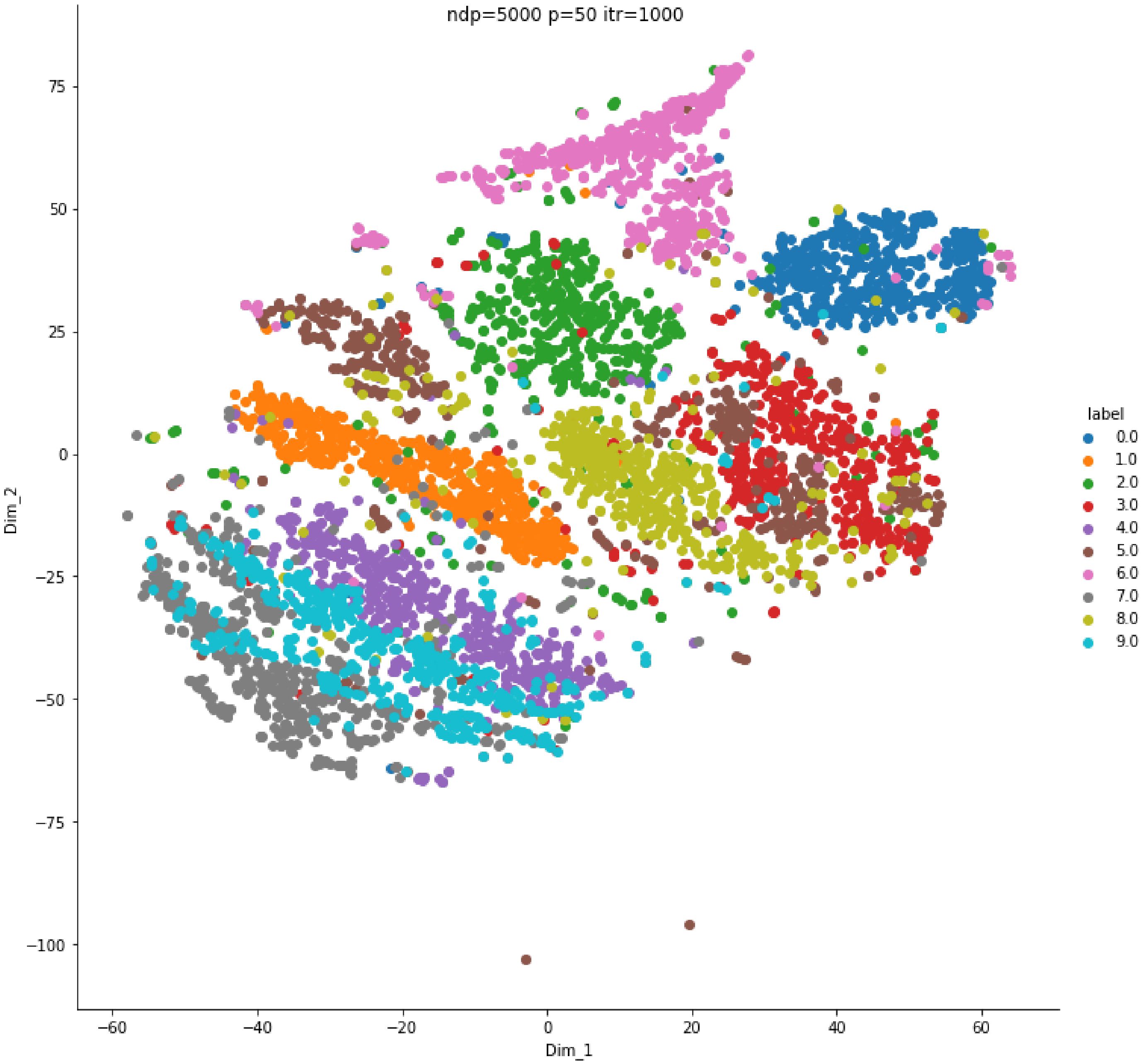

ndp=5000 p=30 itr=8000
100
0
−100
−200
−300
Dim_2
−200
−100
0
100
Dim_1
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0

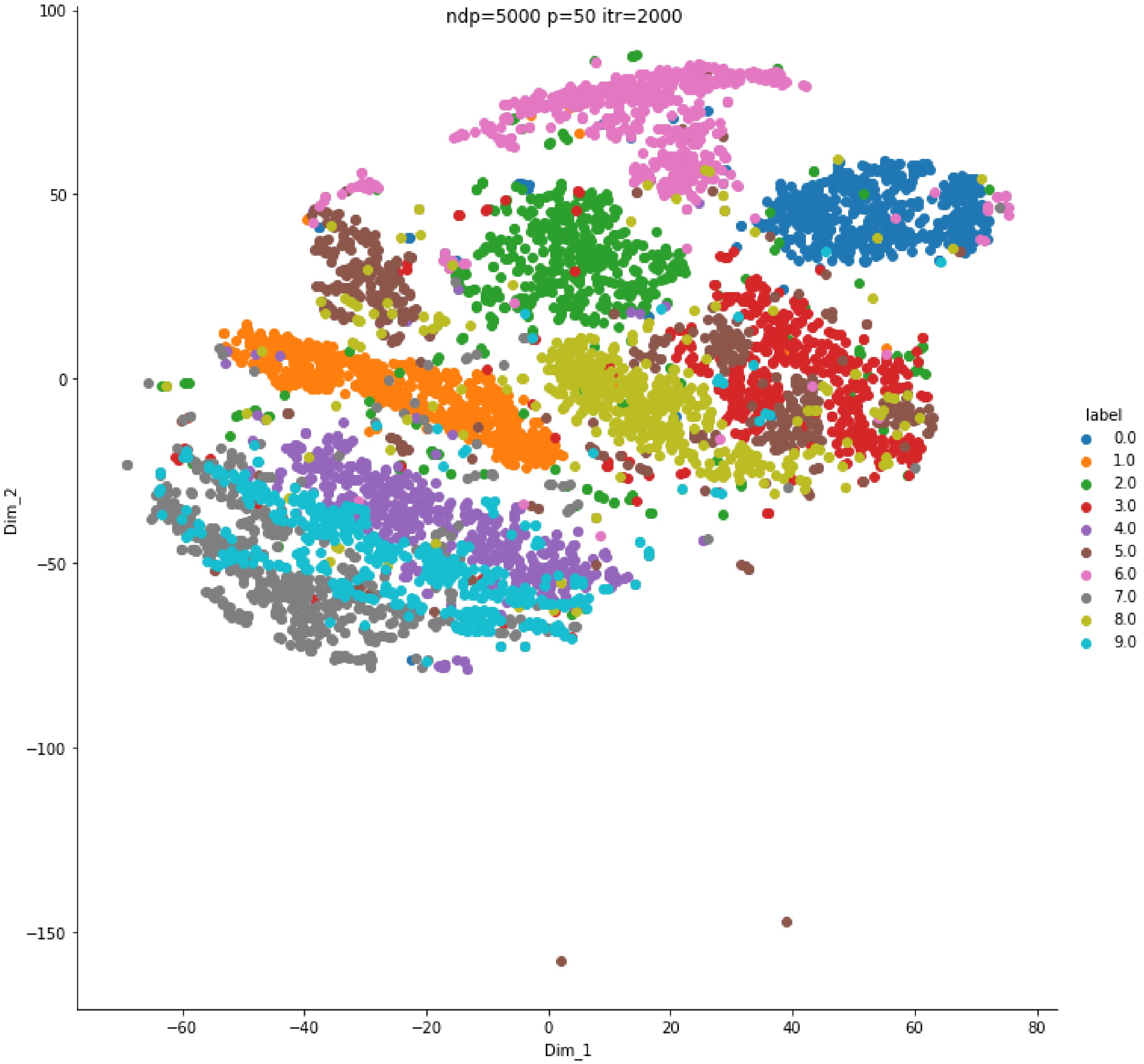

ndp=5000 p=30 itr=9000
Dim_2
100
0
−100
−200
−300
Dim_1
−300
−200
−100
0
100
200
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0

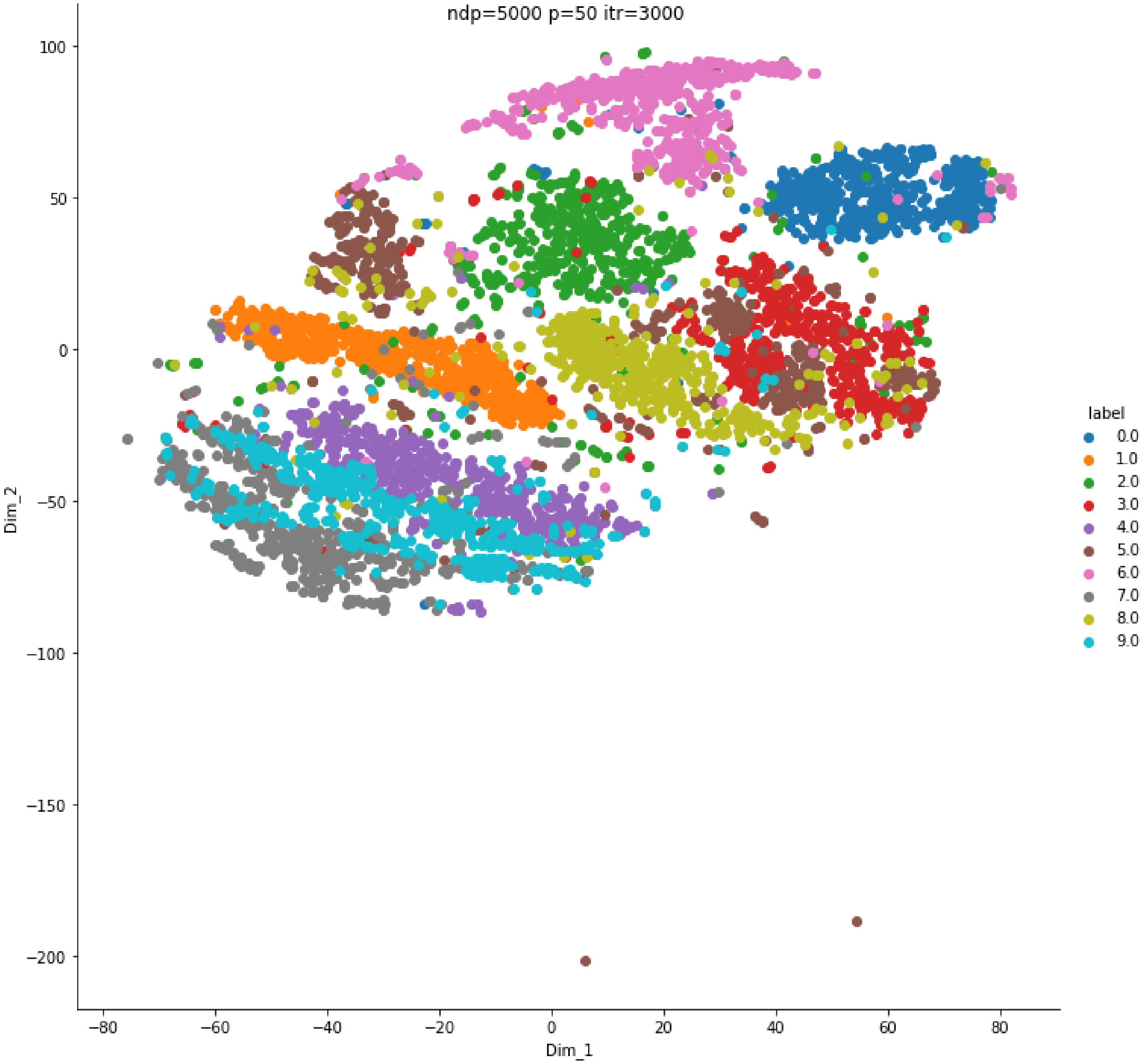


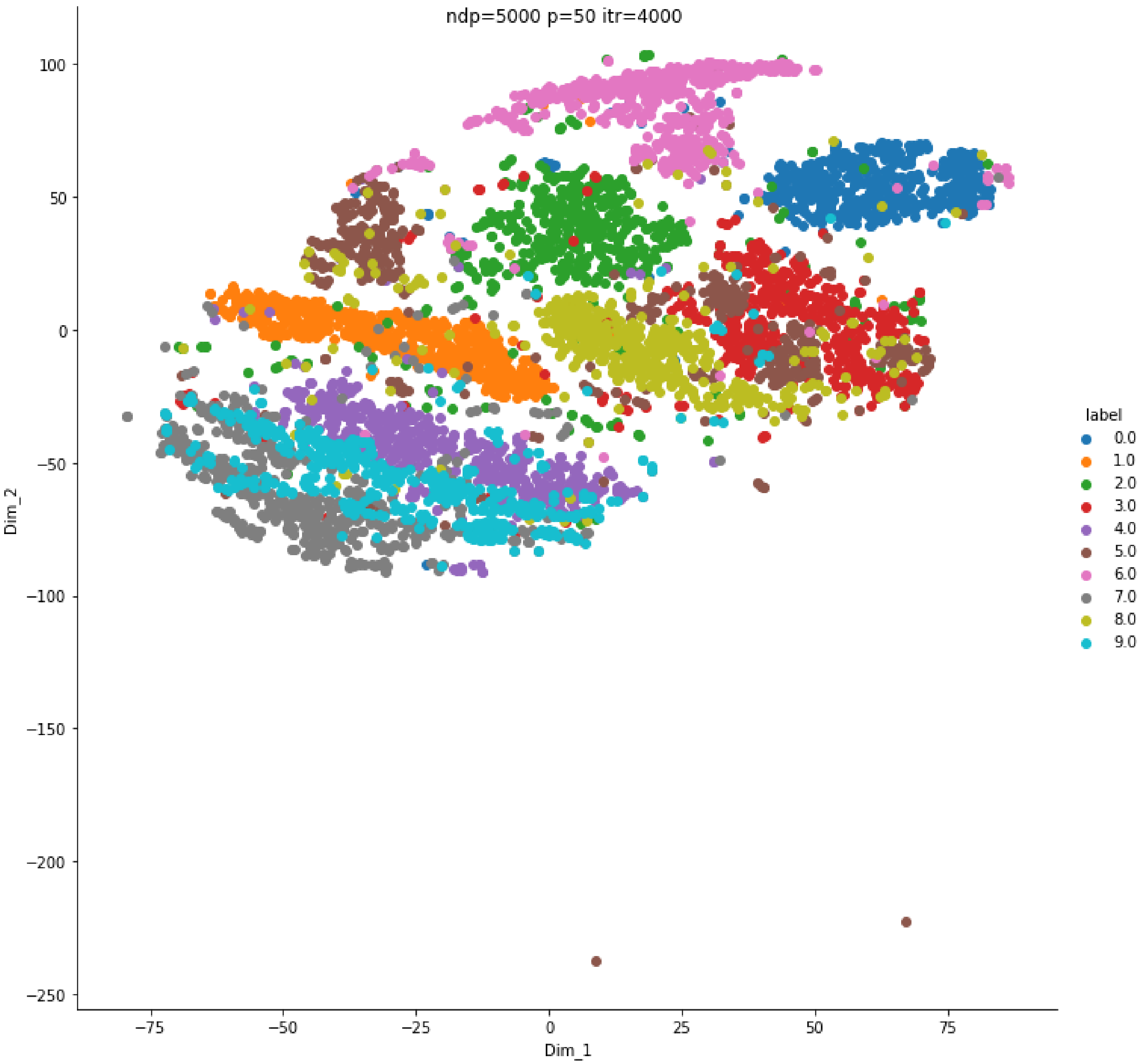
```
In [ ]: genTSNEGif(standardized_data, 5000, 50, range(1000,10001,1000), 't_15000_d_5000_p_50')
```

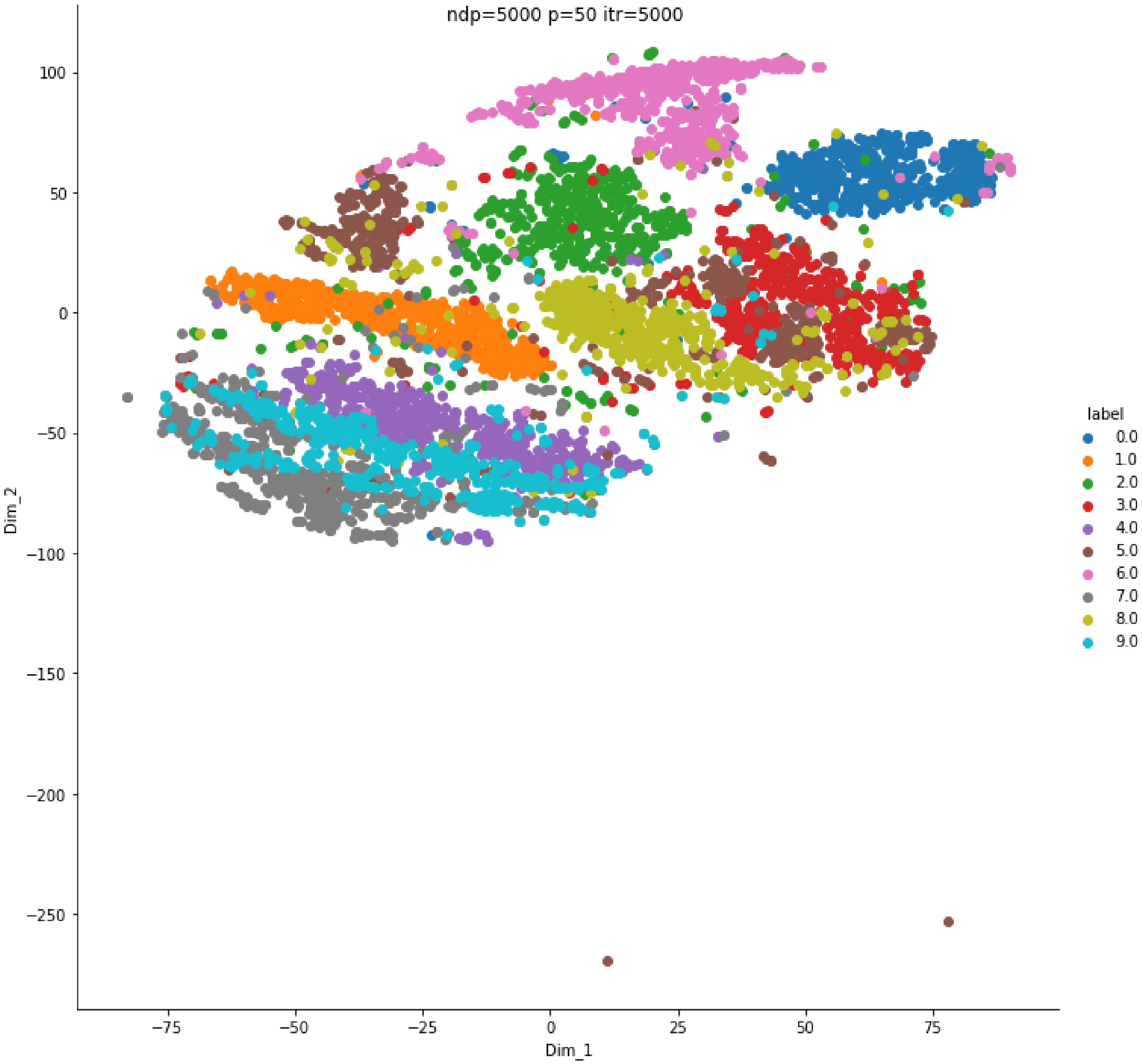
```
No.Of Data Points - 5000, Perplexity - 50, Iterations - range(1000, 10001, 1000), ImageName - t_15000_d_5000_p_50
ndp=5000 p=50 itr=1000 ==> t-SNE done! Time elapsed: 83.9416823387146 seconds
ndp=5000 p=50 itr=2000 ==> t-SNE done! Time elapsed: 137.22521495819092 seconds
ndp=5000 p=50 itr=3000 ==> t-SNE done! Time elapsed: 194.28370428085327 seconds
ndp=5000 p=50 itr=4000 ==> t-SNE done! Time elapsed: 253.0855348110199 seconds
ndp=5000 p=50 itr=5000 ==> t-SNE done! Time elapsed: 314.7297682762146 seconds
ndp=5000 p=50 itr=6000 ==> t-SNE done! Time elapsed: 378.68981170654297 seconds
ndp=5000 p=50 itr=7000 ==> t-SNE done! Time elapsed: 444.68101239204407 seconds
ndp=5000 p=50 itr=8000 ==> t-SNE done! Time elapsed: 514.4695074558258 seconds
ndp=5000 p=50 itr=9000 ==> t-SNE done! Time elapsed: 575.7889912128448 seconds
ndp=5000 p=50 itr=10000 ==> t-SNE done! Time elapsed: 642.7859194278717 seconds
```

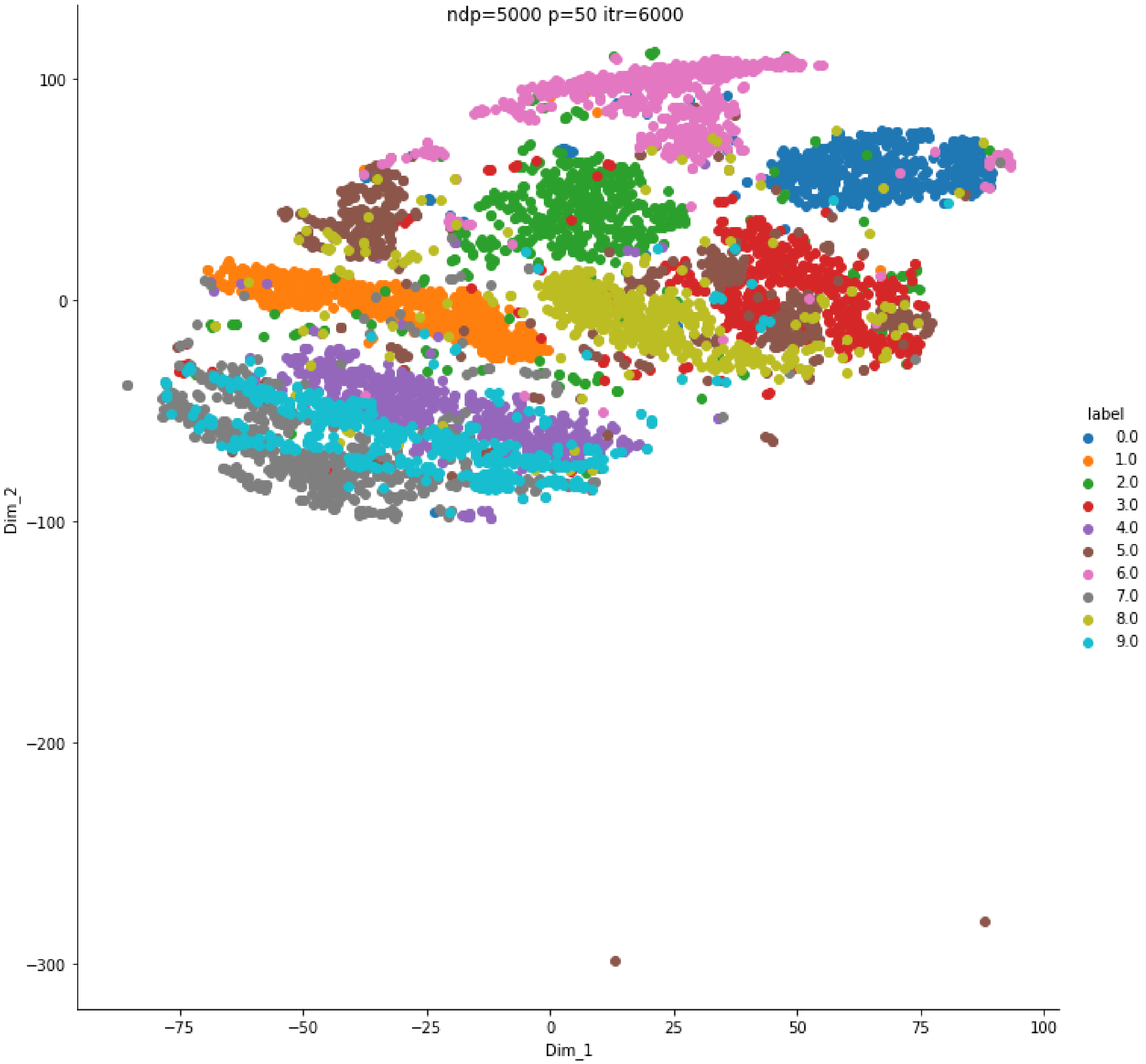

ndp=5000 p=50 itr=1000
75
50
25
0
−25
−50
−75
−100
Dim_2
−60
−40
−20
0
20
40
60
Dim_1
label
● 0.0
● 1.0
● 2.0
● 3.0
● 4.0
● 5.0
● 6.0
● 7.0
● 8.0
● 9.0

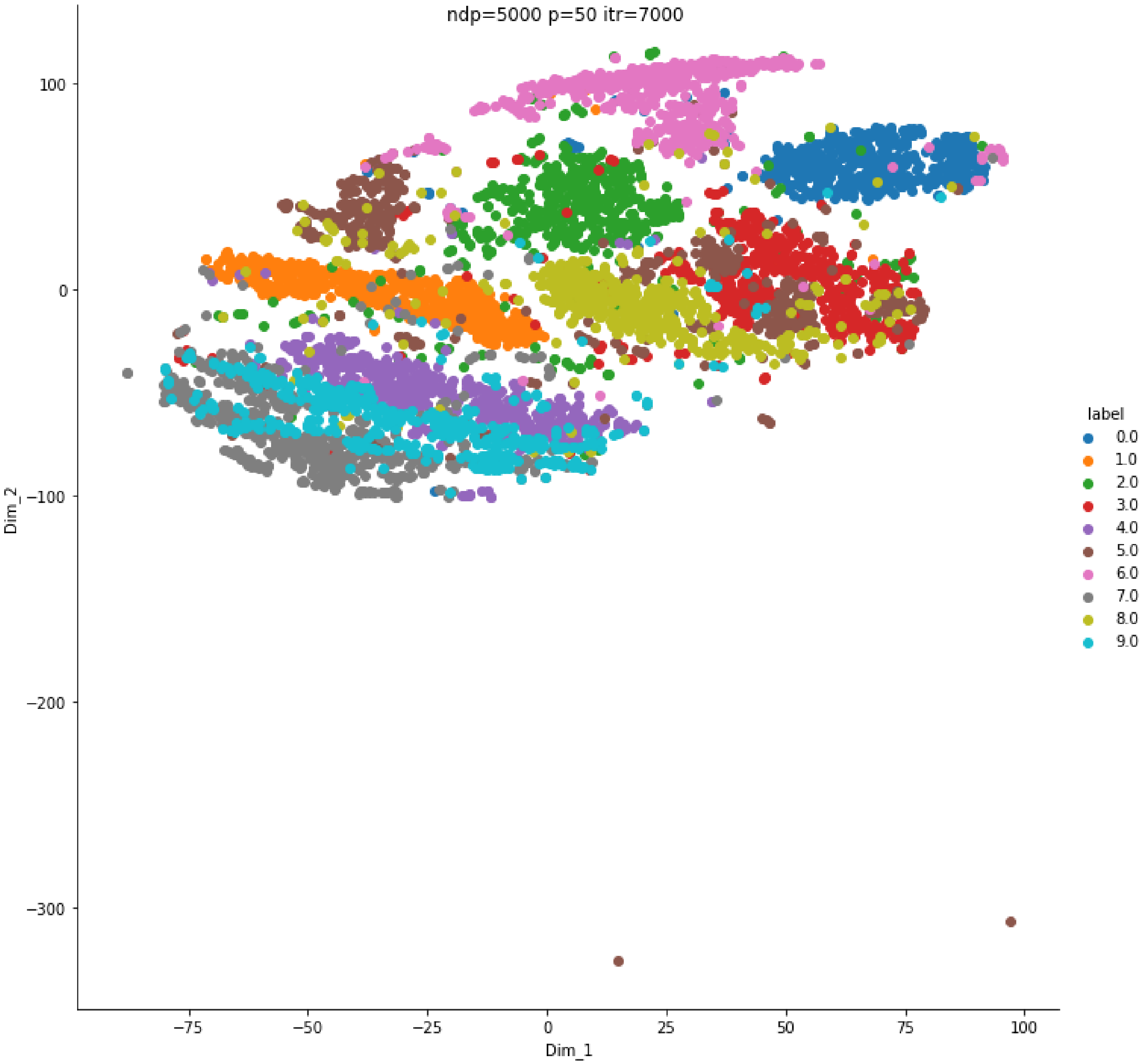

ndp=5000 p=50 itr=2000
100
50
0
−50
−100
−150
Dim_2
−60
−40
−20
0
20
40
60
80
Dim_1
label
● 0.0
● 1.0
● 2.0
● 3.0
● 4.0
● 5.0
● 6.0
● 7.0
● 8.0
● 9.0

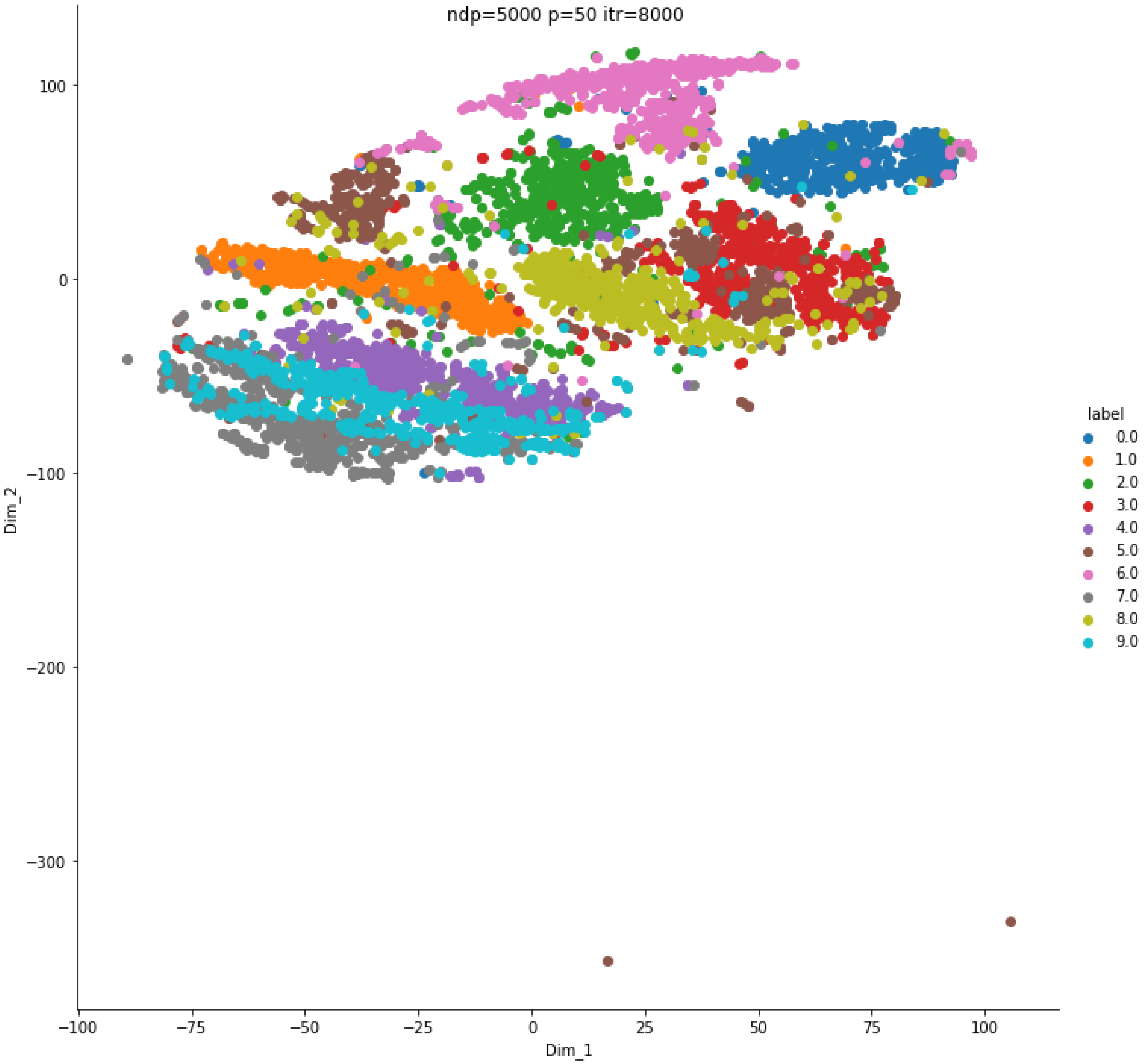

ndp=5000 p=50 itr=3000
100
50
0
−50
−100
−150
−200
Dim_2
−80
−60
−40
−20
0
20
40
60
80
Dim_1
label
● 0.0
● 1.0
● 2.0
● 3.0
● 4.0
● 5.0
● 6.0
● 7.0
● 8.0
● 9.0

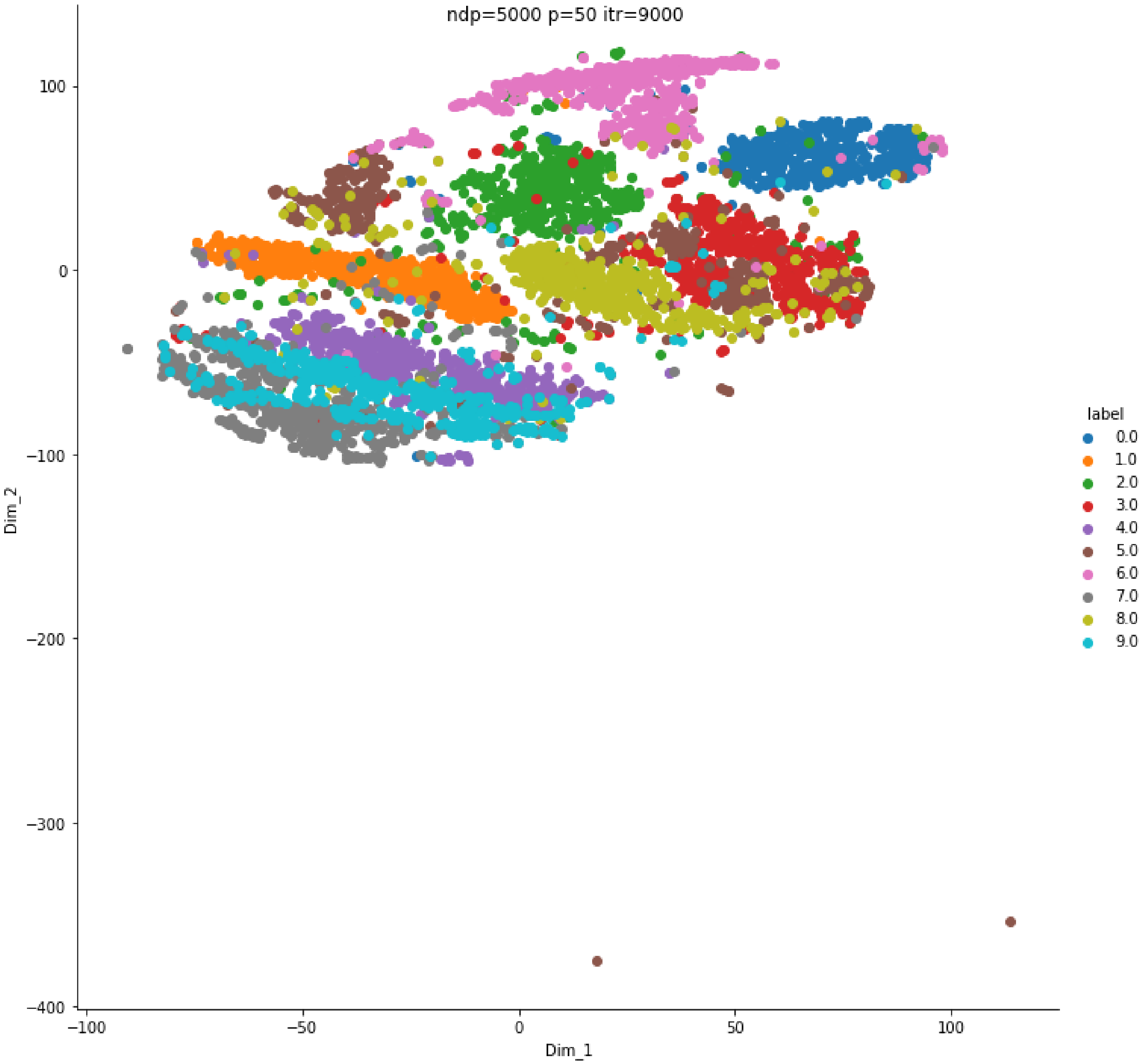

ndp=5000 p=50 itr=4000
100
50
0
−50
−100
−150
−200
−250
Dim_2
−75
−50
−25
0
25
50
75
Dim_1
label
● 0.0
● 1.0
● 2.0
● 3.0
● 4.0
● 5.0
● 6.0
● 7.0
● 8.0
● 9.0

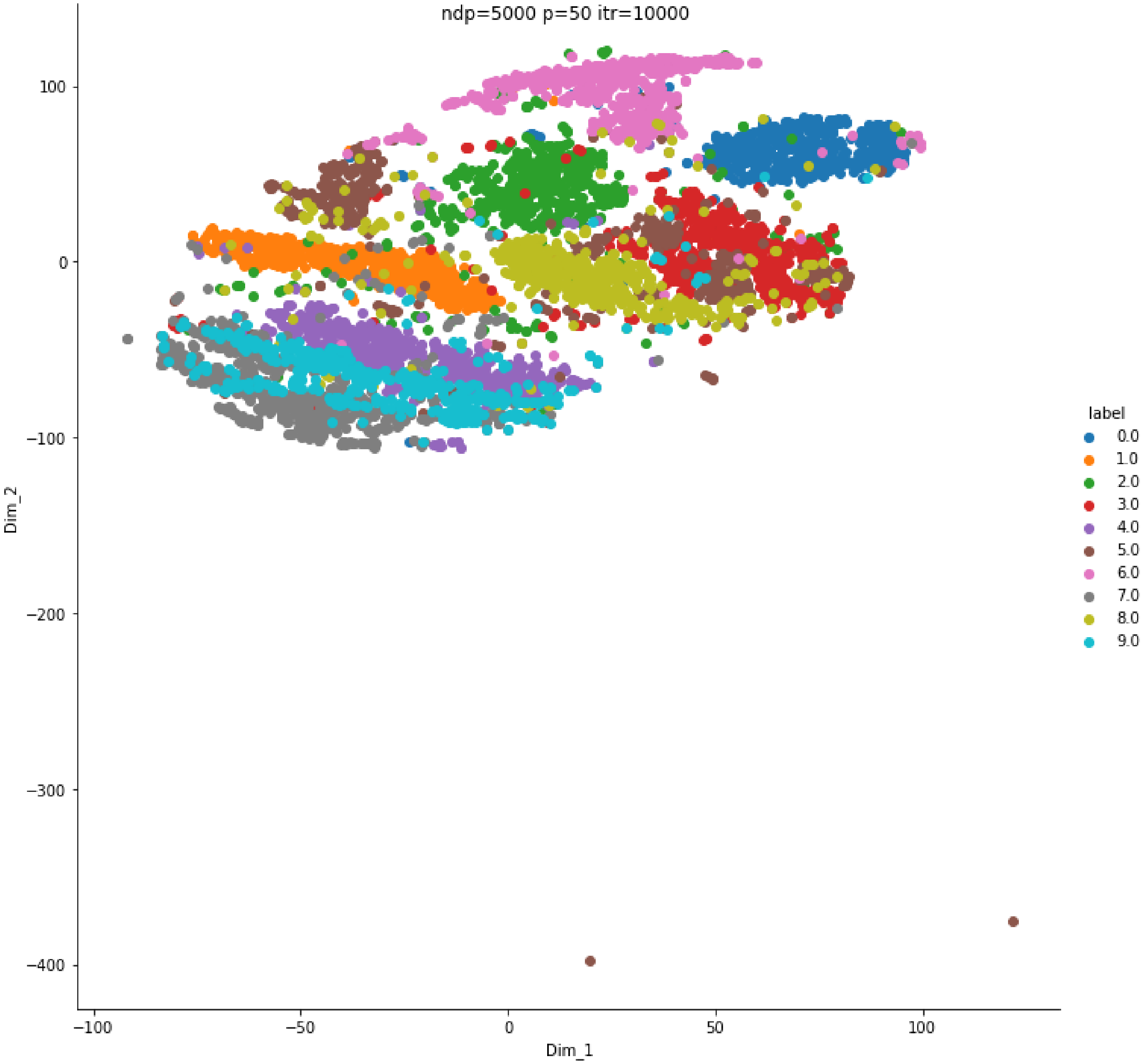

ndp=5000 p=50 itr=5000
100
50
0
−50
−100
−150
−200
−250
Dim_2
−75
−50
−25
0
25
50
75
Dim_1
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0


ndp=5000 p=50 itr=6000
Dim_2
100
0
−100
−200
−300
Dim_1
−75
−50
−25
0
25
50
75
100
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0


ndp=5000 p=50 itr=7000
Dim_2
100
0
−100
−200
−300
Dim_1
−75
−50
−25
0
25
50
75
100
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0


ndp=5000 p=50 itr=8000
100
0
−100
−200
−300
Dim_2
−100
−75
−50
−25
0
25
50
75
100
Dim_1
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0

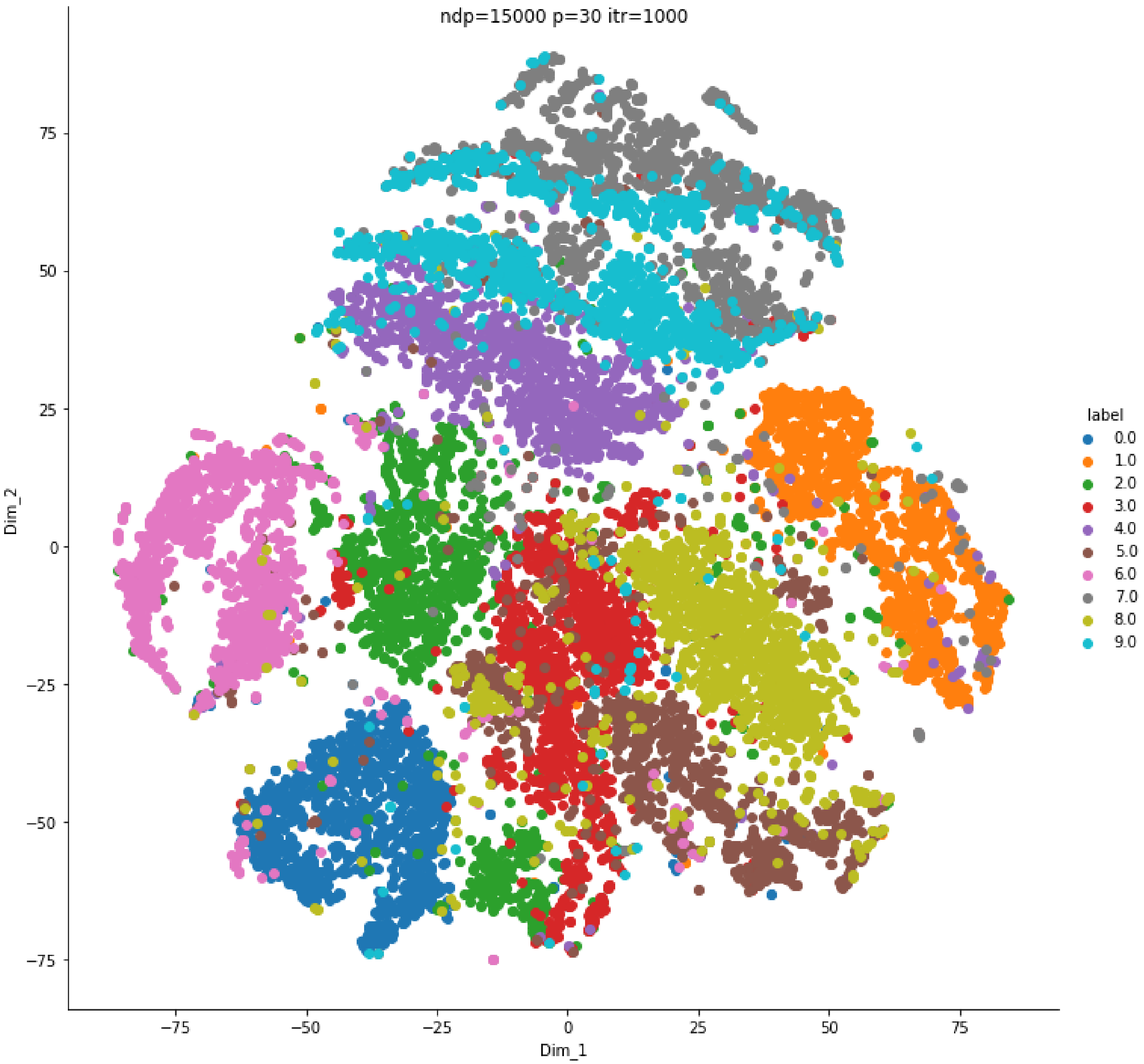

ndp=5000 p=50 itr=9000
100
0
−100
−200
−300
−400
Dim_2
−100
−50
0
50
100
Dim_1
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0

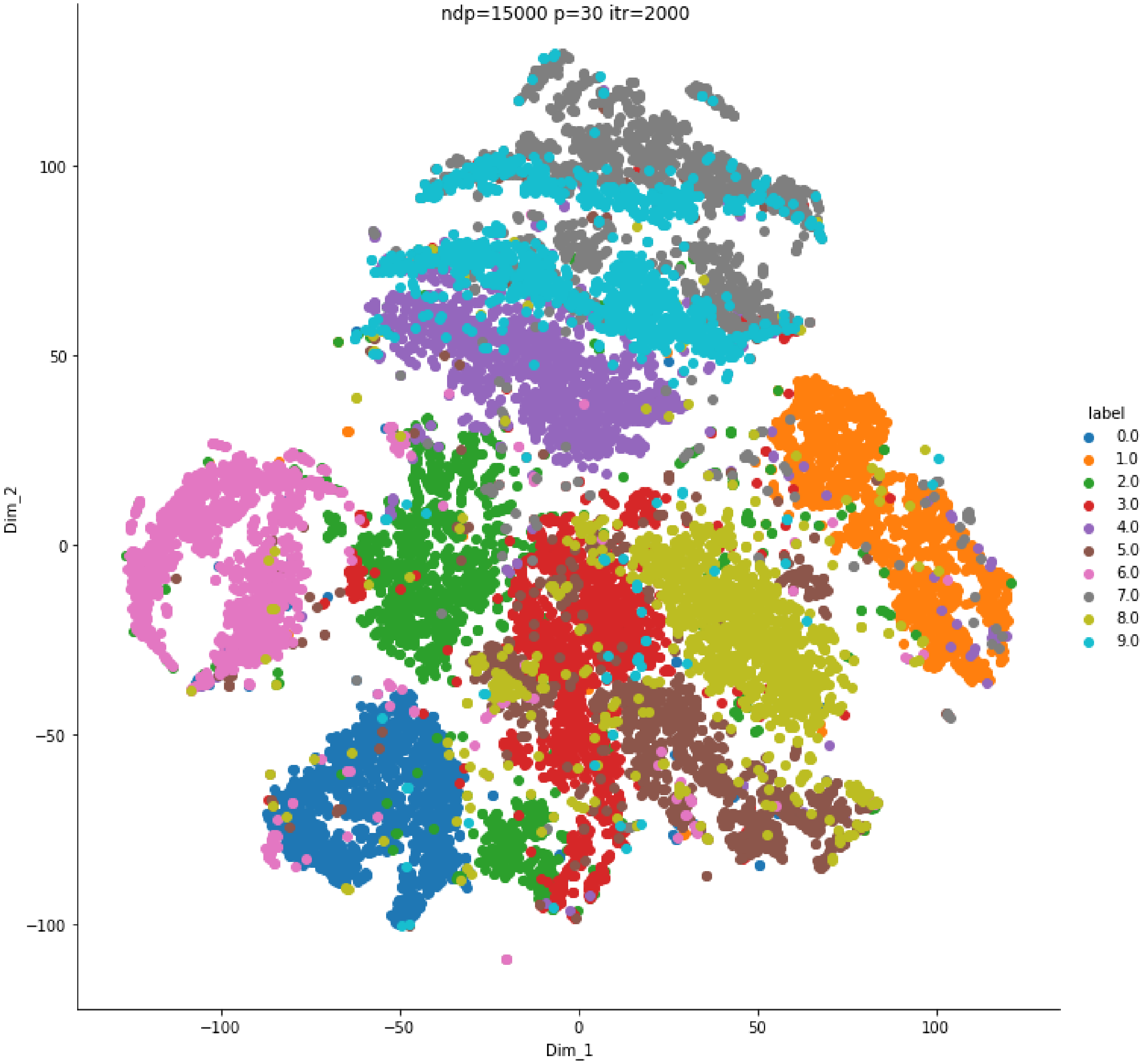


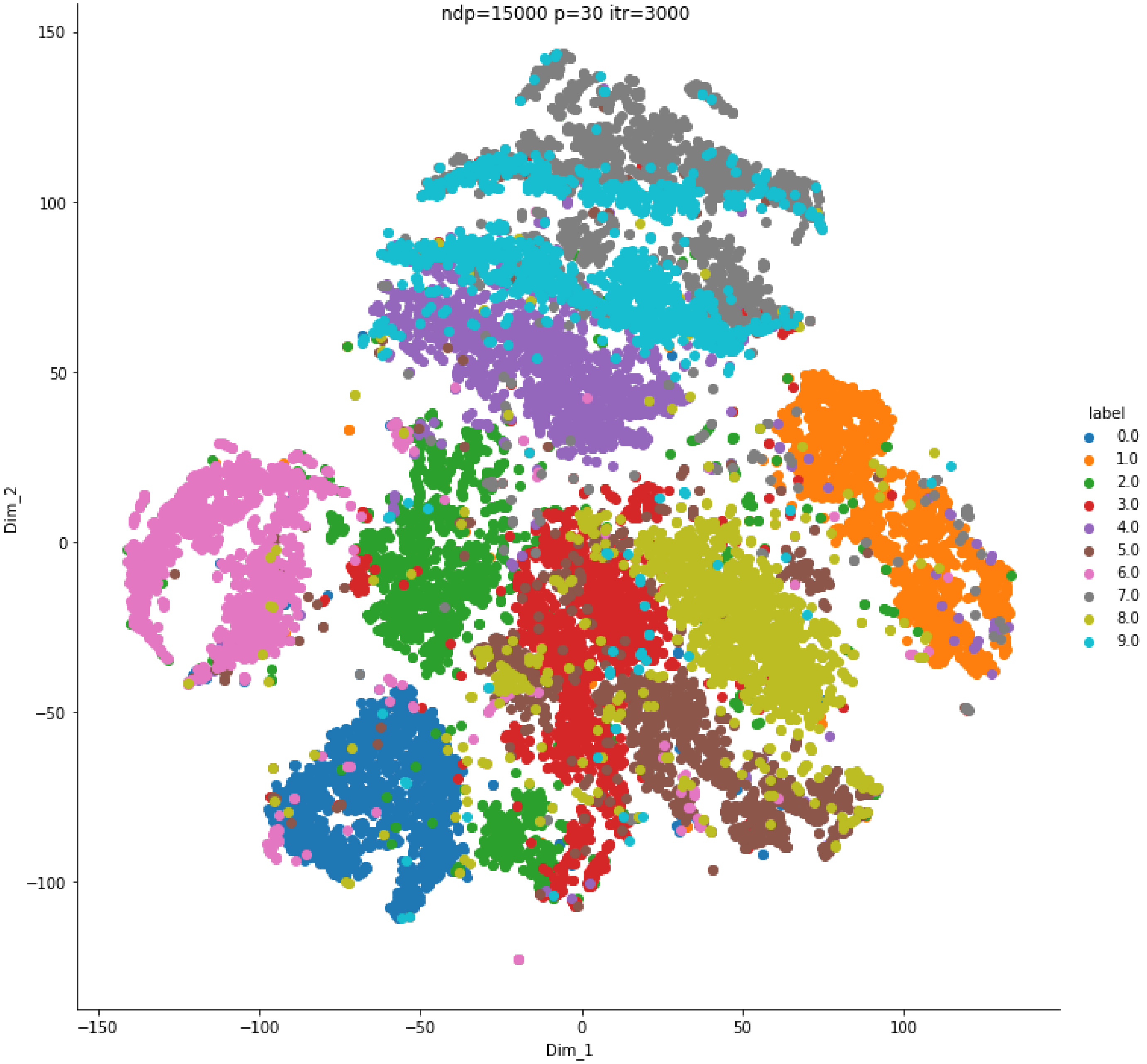
1.1.3 t-SNE over 15000 data points

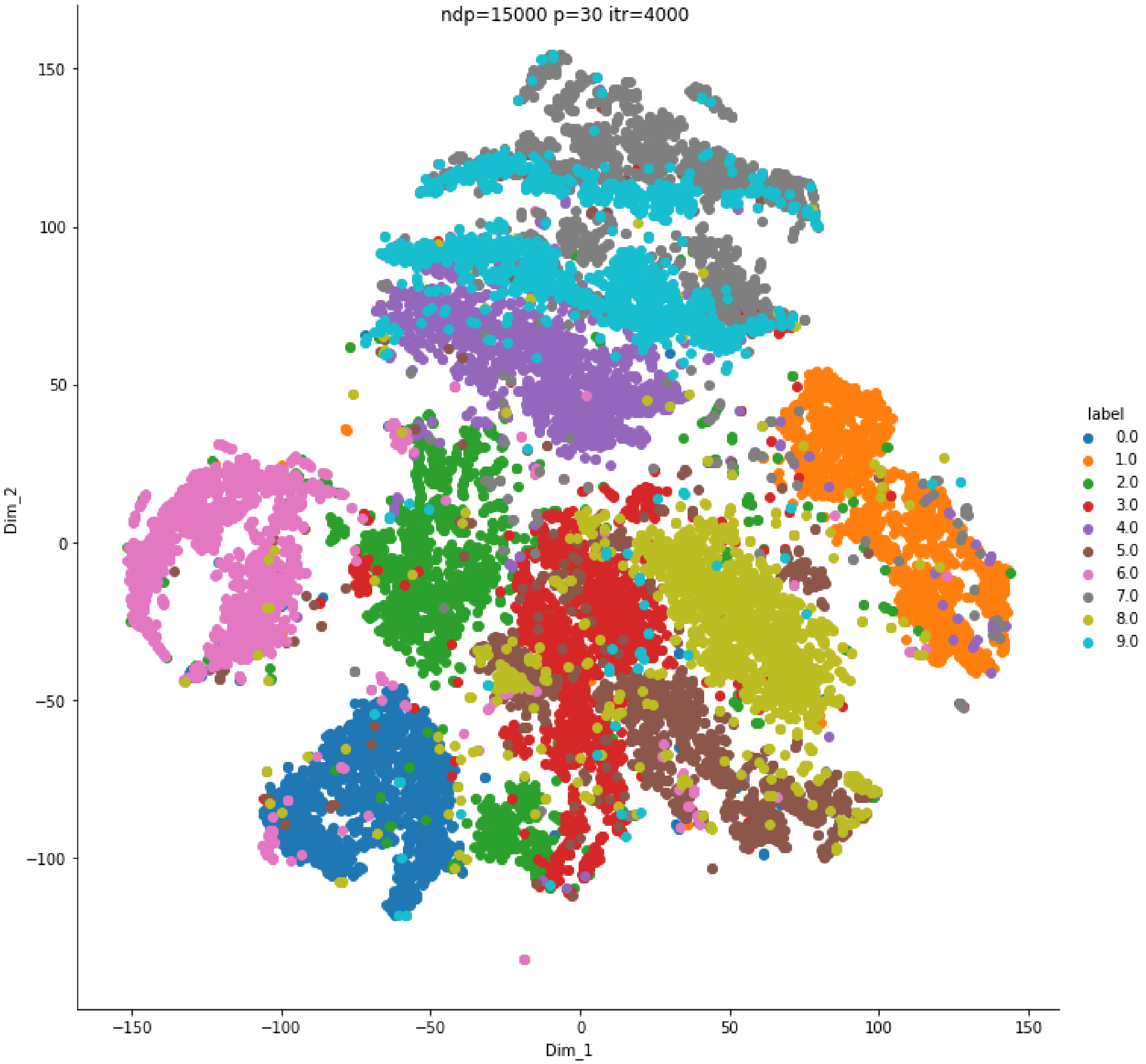
```
In [ ]: genTSNEGif(standardized_data, 15000, 30, range(1000,10001,1000), 't_15000_d_15000_p_30')
```

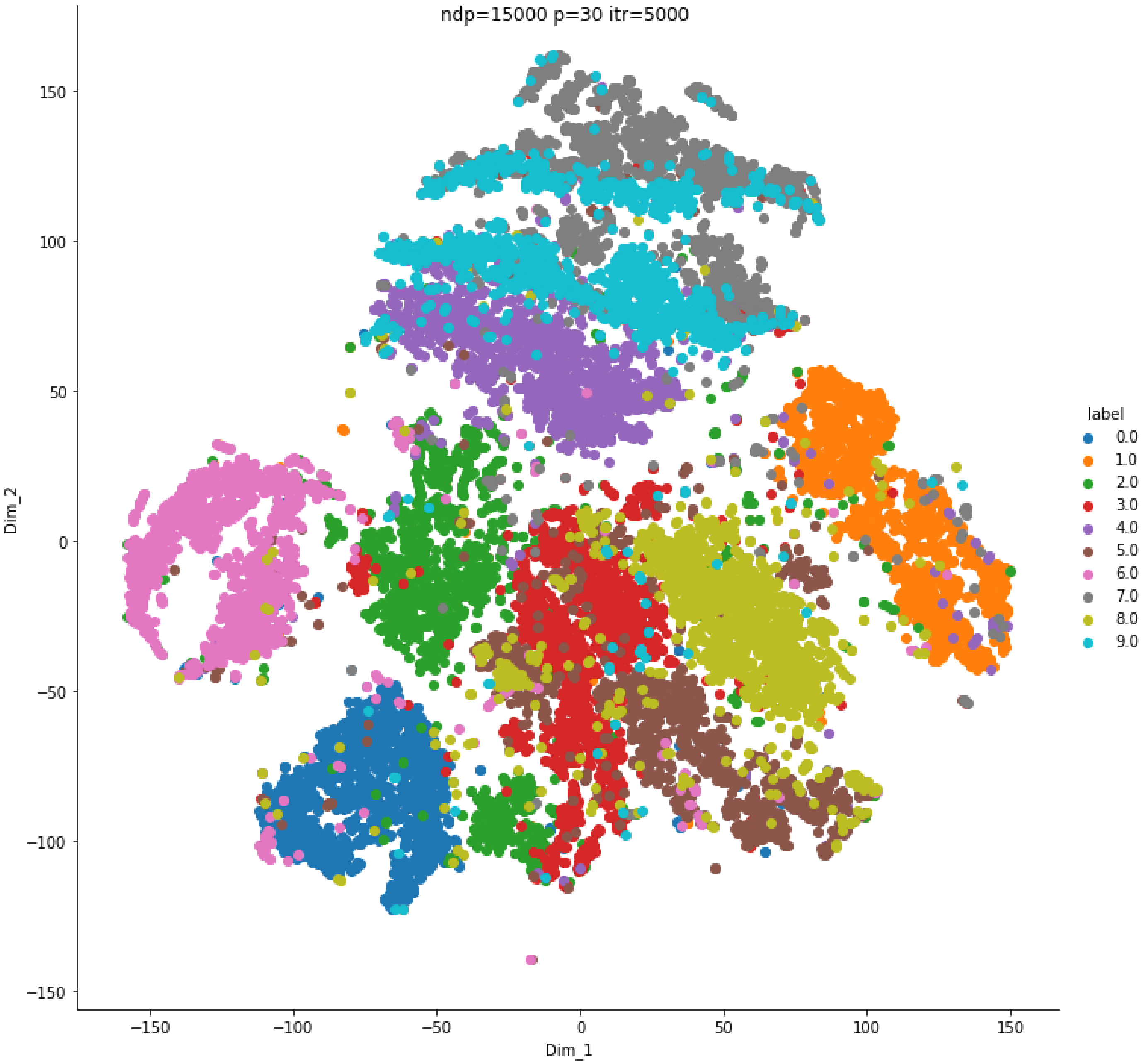
```
No.Of Data Points - 15000, Perplexity - 30, Iterations - range(1000, 10001, 1000), ImageName - t_15000_d_15000_p_30
ndp=15000 p=30 itr=1000 ==> t-SNE done! Time elapsed: 382.7180435657501 seconds
ndp=15000 p=30 itr=2000 ==> t-SNE done! Time elapsed: 523.3870565891266 seconds
ndp=15000 p=30 itr=3000 ==> t-SNE done! Time elapsed: 666.2103087902069 seconds
ndp=15000 p=30 itr=4000 ==> t-SNE done! Time elapsed: 811.8709771633148 seconds
ndp=15000 p=30 itr=5000 ==> t-SNE done! Time elapsed: 946.0533254146576 seconds
ndp=15000 p=30 itr=6000 ==> t-SNE done! Time elapsed: 1095.3283324241638 seconds
ndp=15000 p=30 itr=7000 ==> t-SNE done! Time elapsed: 1233.597757101059 seconds
ndp=15000 p=30 itr=8000 ==> t-SNE done! Time elapsed: 1375.592225074768 seconds
ndp=15000 p=30 itr=9000 ==> t-SNE done! Time elapsed: 1516.2682173252106 seconds
ndp=15000 p=30 itr=10000 ==> t-SNE done! Time elapsed: 1659.1642746925354 seconds
```

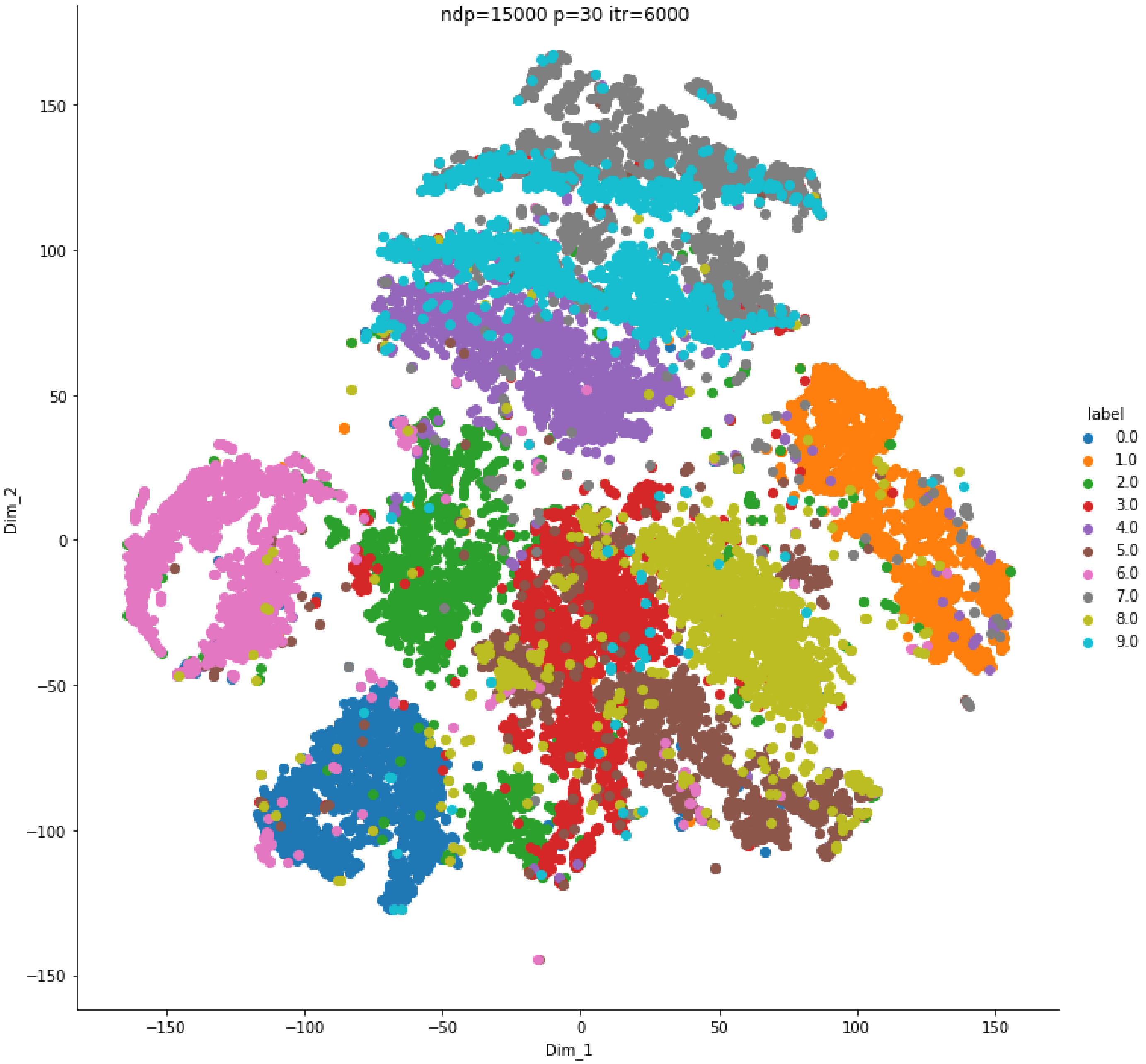

ndp=15000 p=30 itr=1000
Dim_2
Dim_1
75
50
25
0
−25
−50
−75
−75
−50
−25
0
25
50
75
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0

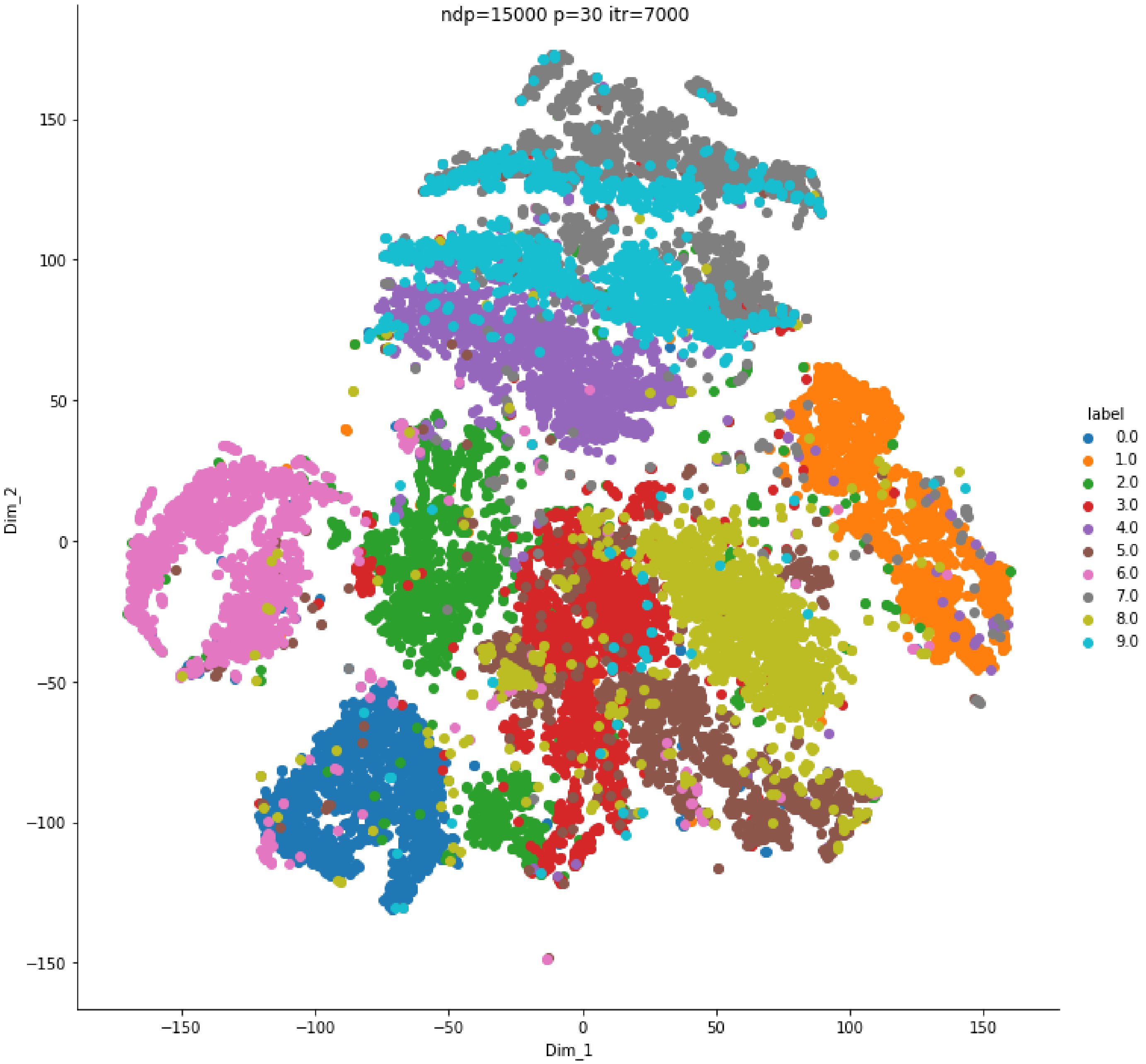

ndp=15000 p=30 itr=2000
Dim_2
100
50
0
−50
−100
Dim_1
−100
−50
0
50
100
label
● 0.0
● 1.0
● 2.0
● 3.0
● 4.0
● 5.0
● 6.0
● 7.0
● 8.0
● 9.0

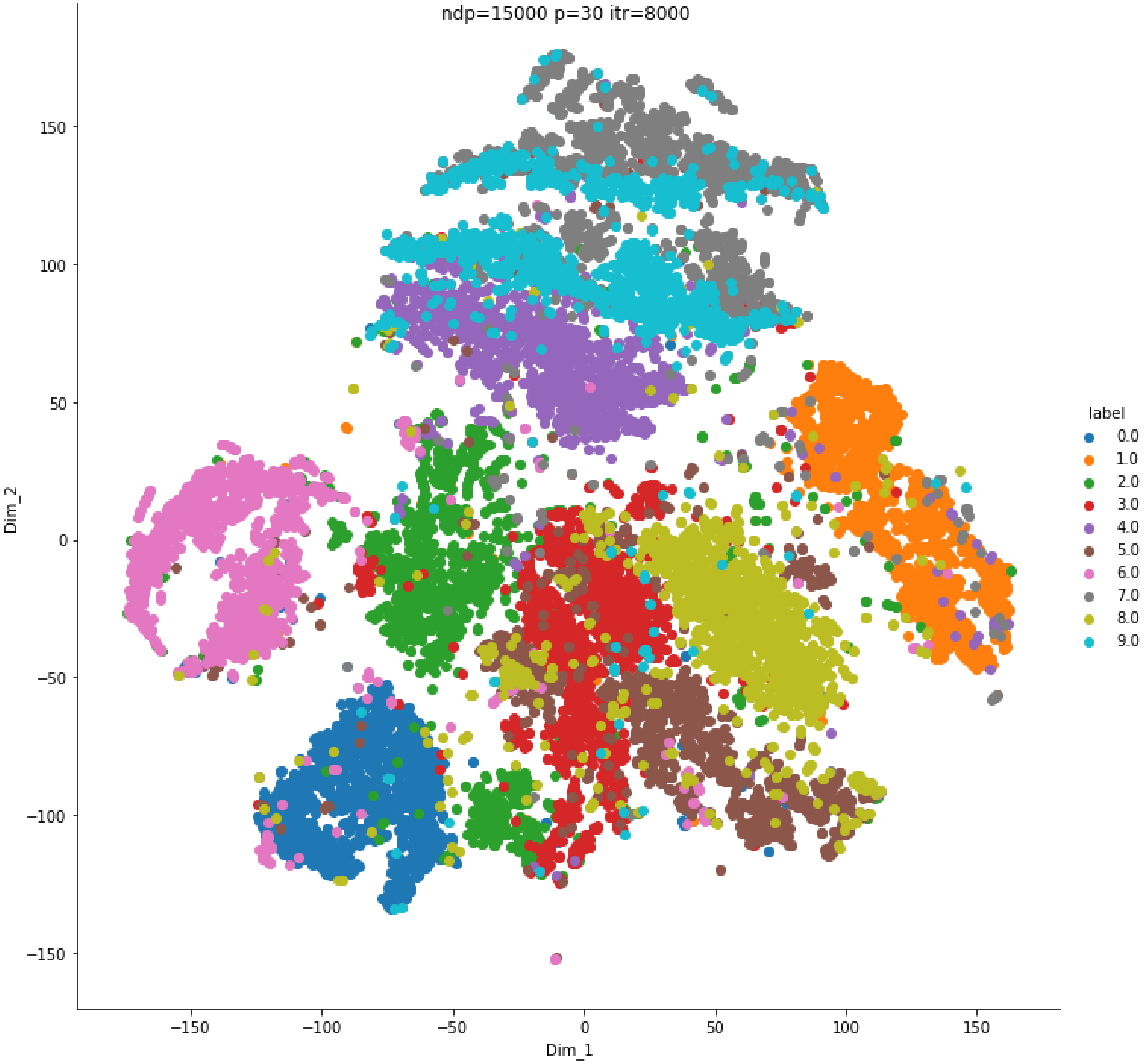

ndp=15000 p=30 itr=3000
150
100
50
0
−50
−100
Dim_2
−150
−100
−50
0
50
100
Dim_1
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0

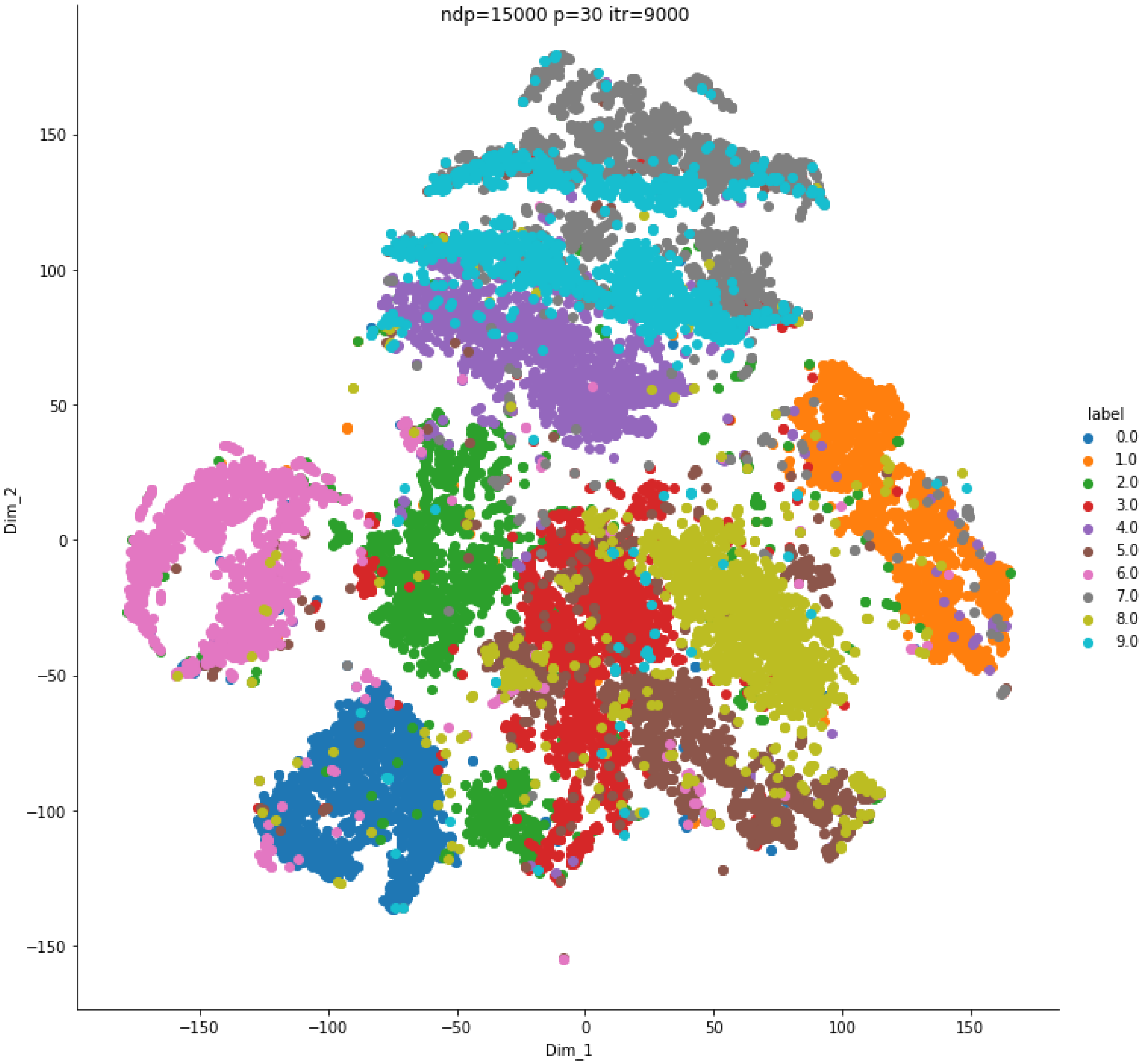

ndp=15000 p=30 itr=4000
150
100
50
0
−50
−100
Dim_2
−150
−100
−50
0
50
100
150
Dim_1
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0

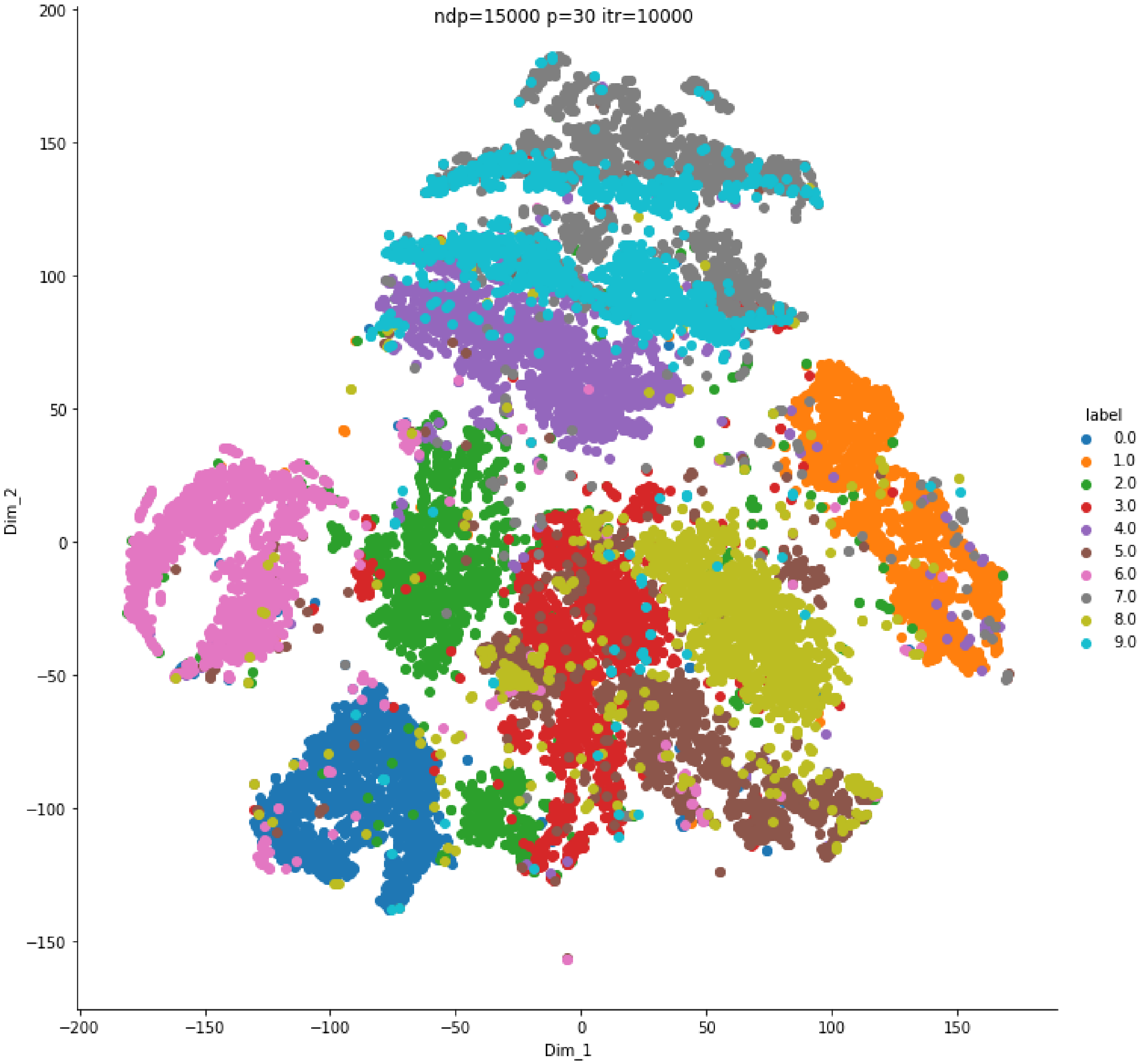

ndp=15000 p=30 itr=5000
Dim_2
150
100
50
0
−50
−100
−150
Dim_1
−150
−100
−50
0
50
100
150
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0


ndp=15000 p=30 itr=6000
Dim_2
150
100
50
0
−50
−100
−150
Dim_1
−150
−100
−50
0
50
100
150
label
● 0.0
● 1.0
● 2.0
● 3.0
● 4.0
● 5.0
● 6.0
● 7.0
● 8.0
● 9.0

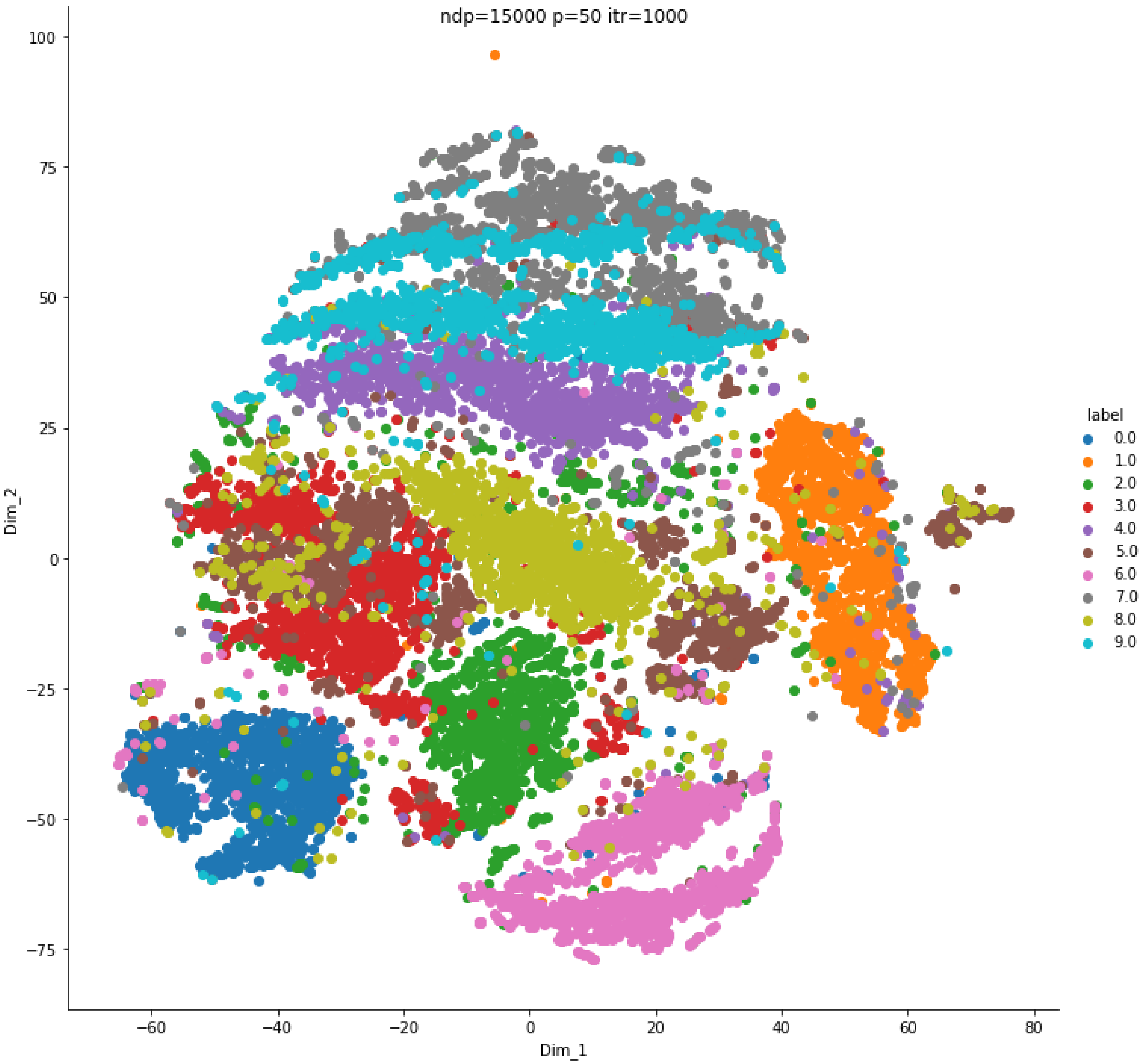

ndp=15000 p=30 itr=7000
Dim_2
Dim_1
150
100
50
0
−50
−100
−150
−150
−100
−50
0
50
100
150
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0

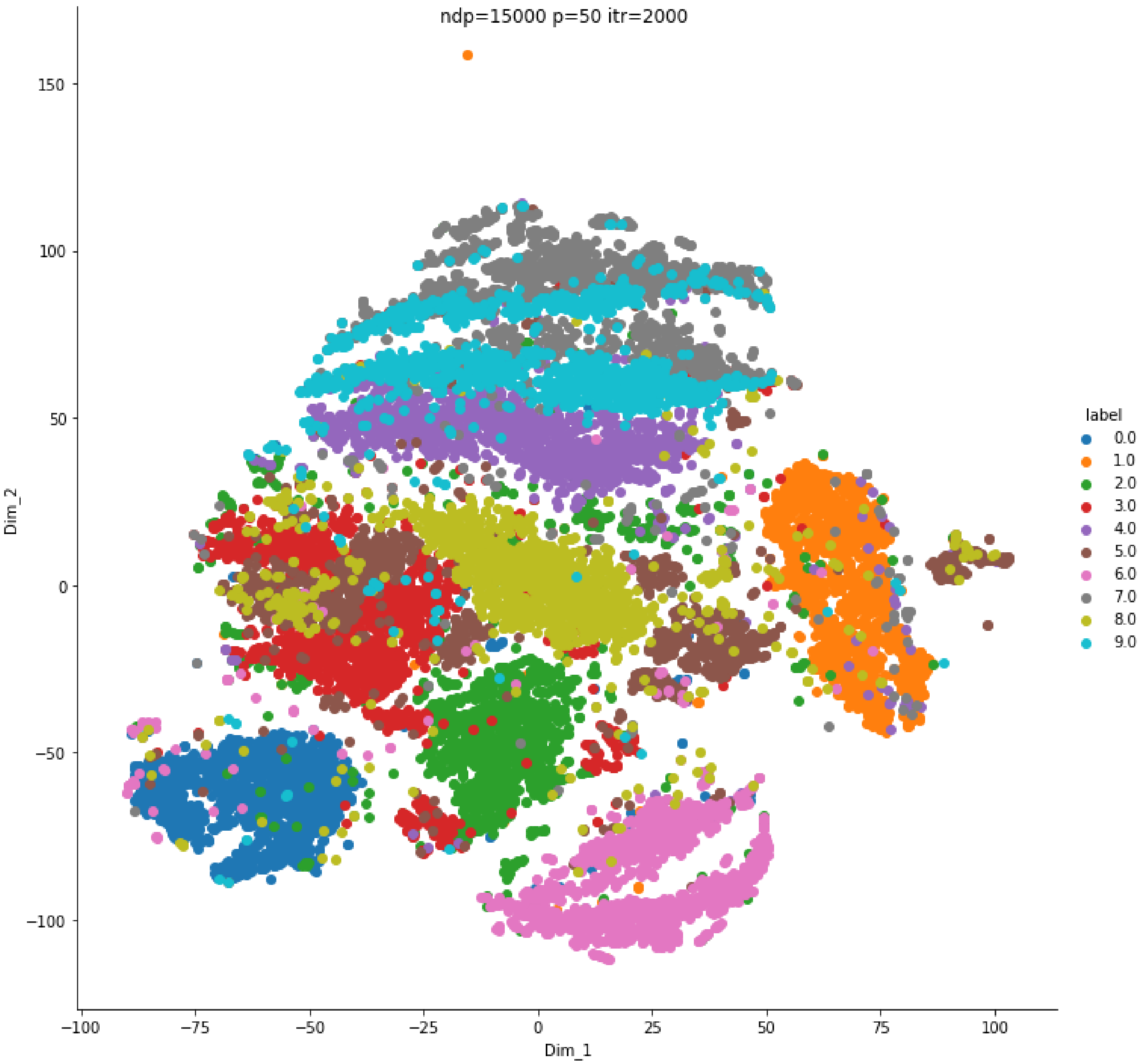

ndp=15000 p=30 itr=8000
Dim_2
Dim_1
150
100
50
0
−50
−100
−150
−150
−100
−50
0
50
100
150
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0

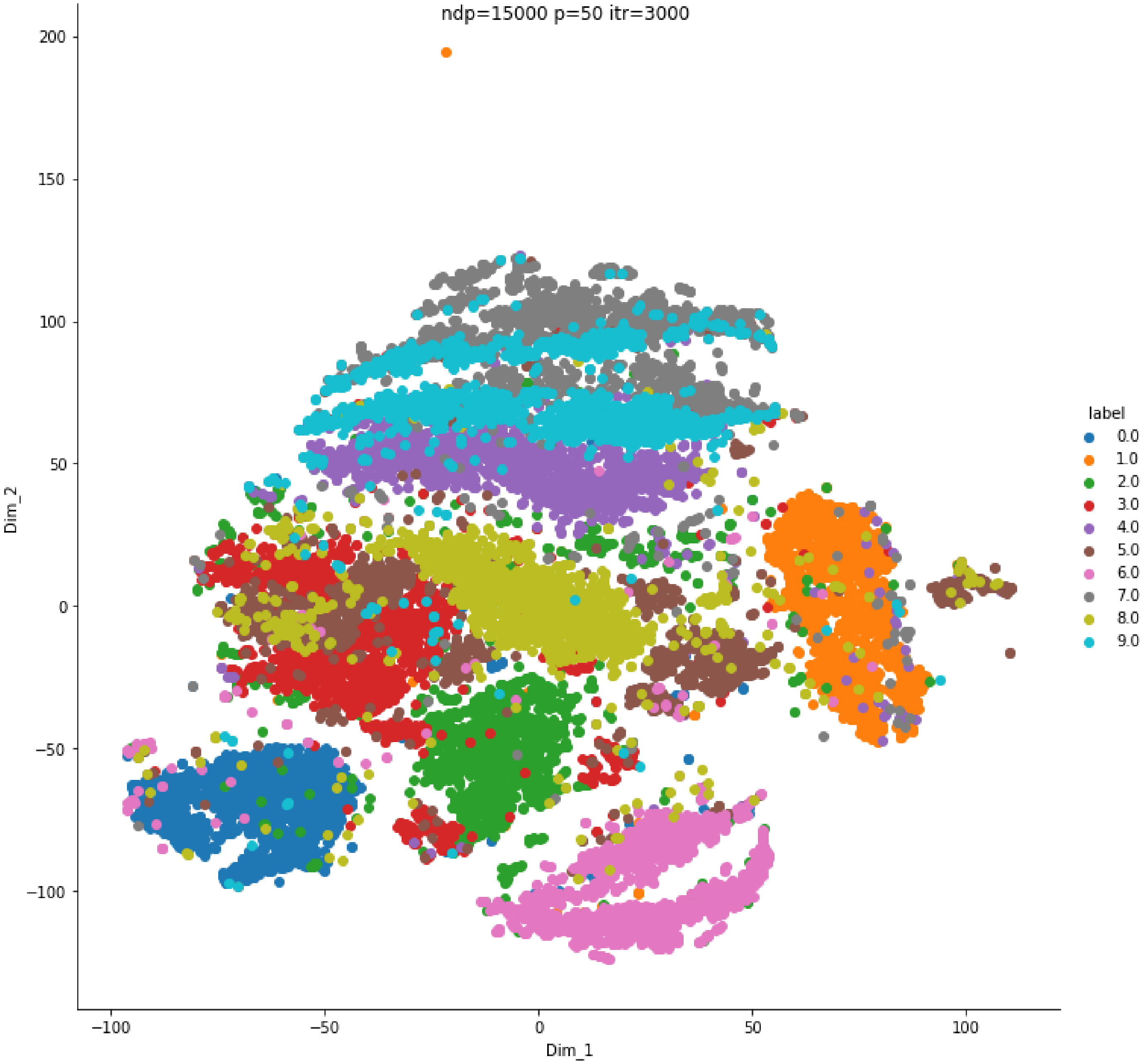

ndp=15000 p=30 itr=9000
Dim_2
Dim_1
150
100
50
0
−50
−100
−150
−150
−100
−50
0
50
100
150
label
● 0.0
● 1.0
● 2.0
● 3.0
● 4.0
● 5.0
● 6.0
● 7.0
● 8.0
● 9.0

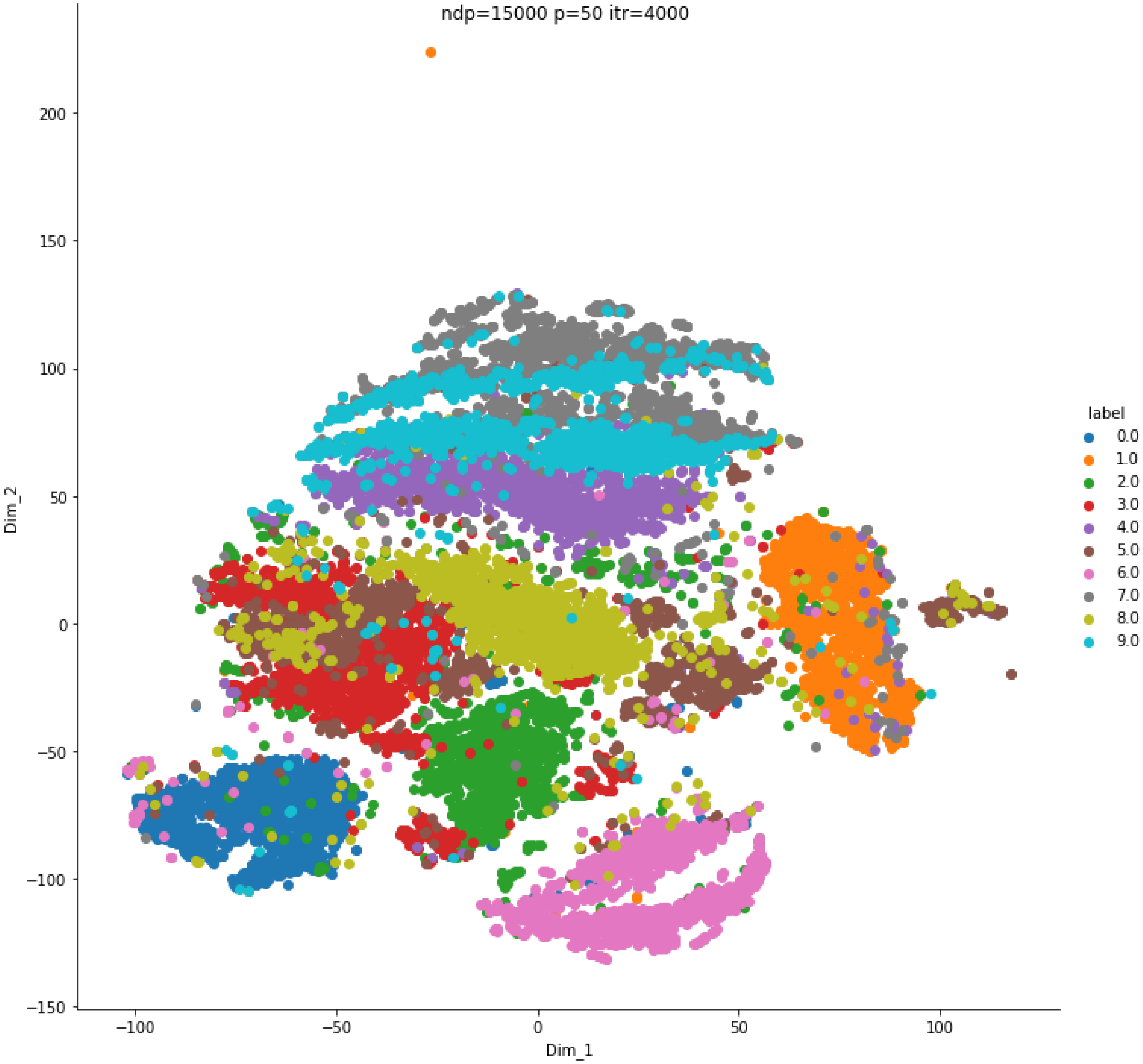


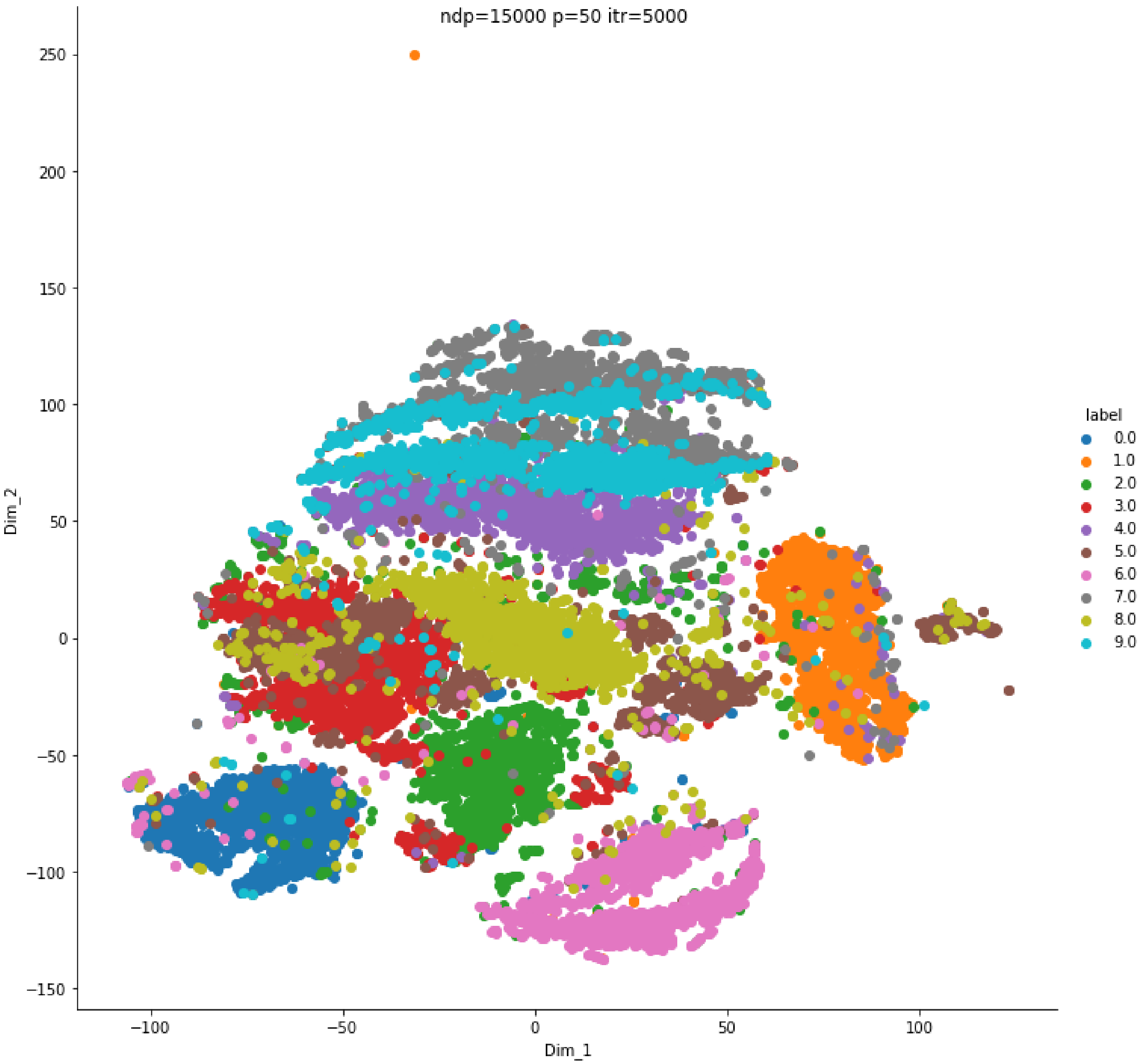
```
In [ ]: genTSNEGif(standardized_data, 15000, 50, range(1000,10001,1000), 't_15000_d_15000_p_50')

No.Of Data Points - 15000, Perplexity - 50, Iterations - range(1000, 10001, 1000), ImageName - t_15000_d_15000_p_50
ndp=15000 p=50 itr=1000 ==> t-SNE done! Time elapsed: 490.88792157173157 seconds
ndp=15000 p=50 itr=2000 ==> t-SNE done! Time elapsed: 672.6919836997986 seconds
ndp=15000 p=50 itr=3000 ==> t-SNE done! Time elapsed: 866.8310749530792 seconds
ndp=15000 p=50 itr=4000 ==> t-SNE done! Time elapsed: 1070.9834036827087 seconds
ndp=15000 p=50 itr=5000 ==> t-SNE done! Time elapsed: 1280.3677475452423 seconds
ndp=15000 p=50 itr=6000 ==> t-SNE done! Time elapsed: 1484.575926065445 seconds
ndp=15000 p=50 itr=7000 ==> t-SNE done! Time elapsed: 1702.2496531009674 seconds
ndp=15000 p=50 itr=8000 ==> t-SNE done! Time elapsed: 1953.8452818393707 seconds
ndp=15000 p=50 itr=9000 ==> t-SNE done! Time elapsed: 2354.1894524097443 seconds
ndp=15000 p=50 itr=10000 ==> t-SNE done! Time elapsed: 2754.3687765598297 seconds
```

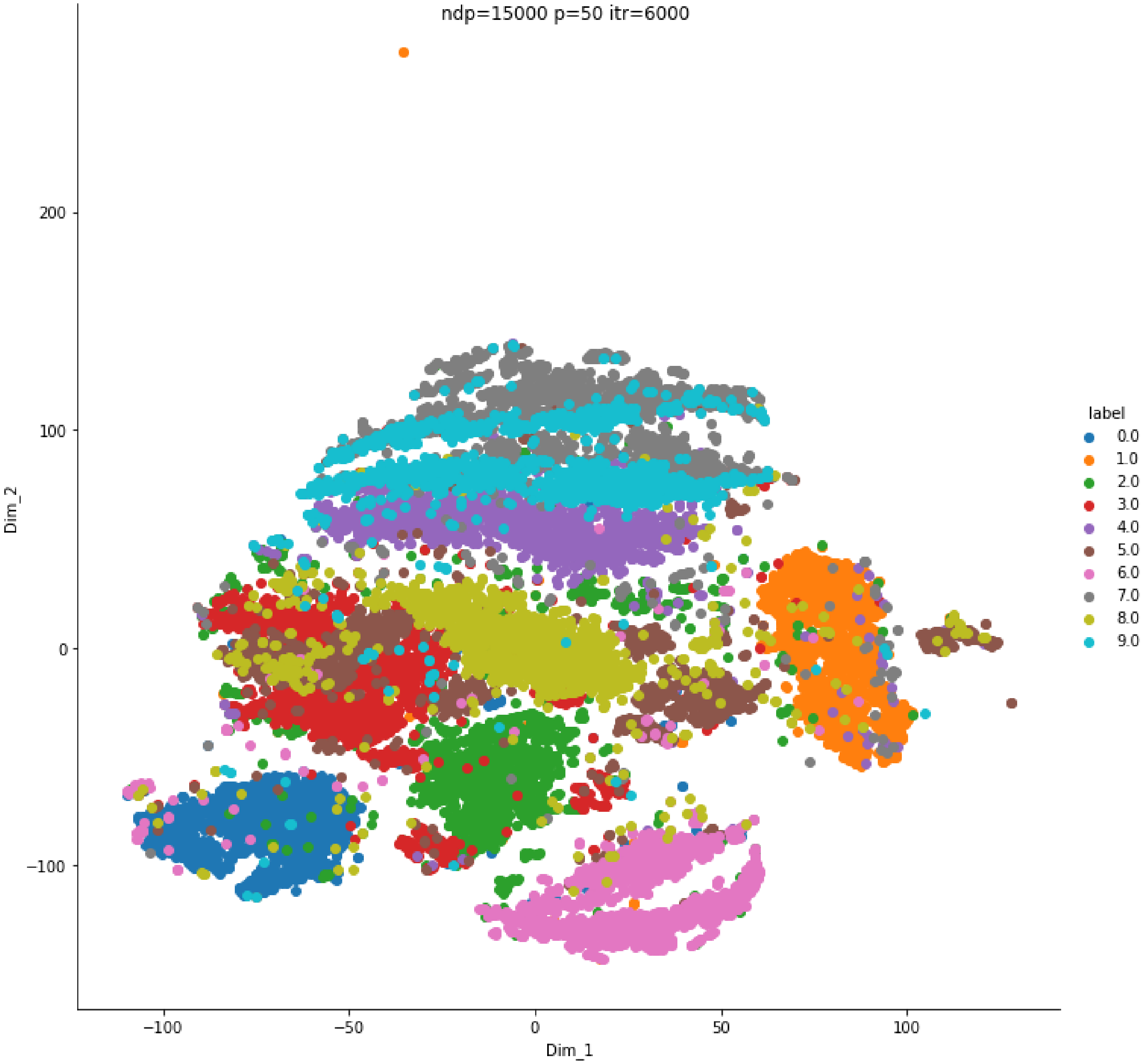

ndp=15000 p=50 itr=1000
100
75
50
25
0
−25
−50
−75
Dim_2
−60
−40
−20
0
20
40
60
80
Dim_1
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0

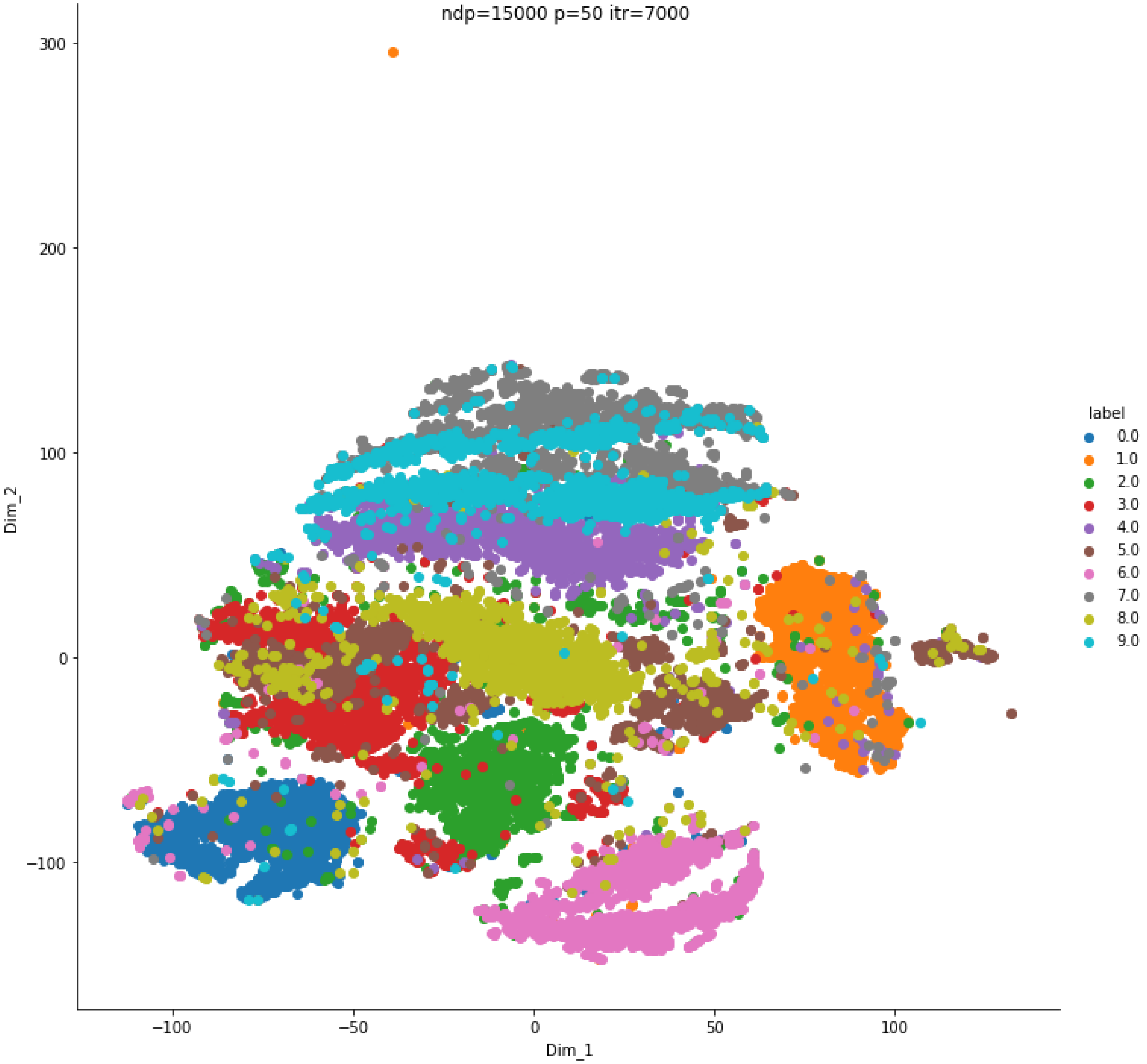

ndp=15000 p=50 itr=2000
150
100
50
0
−50
−100
Dim_2
−100
−75
−50
−25
0
25
50
75
100
Dim_1
label
● 0.0
● 1.0
● 2.0
● 3.0
● 4.0
● 5.0
● 6.0
● 7.0
● 8.0
● 9.0

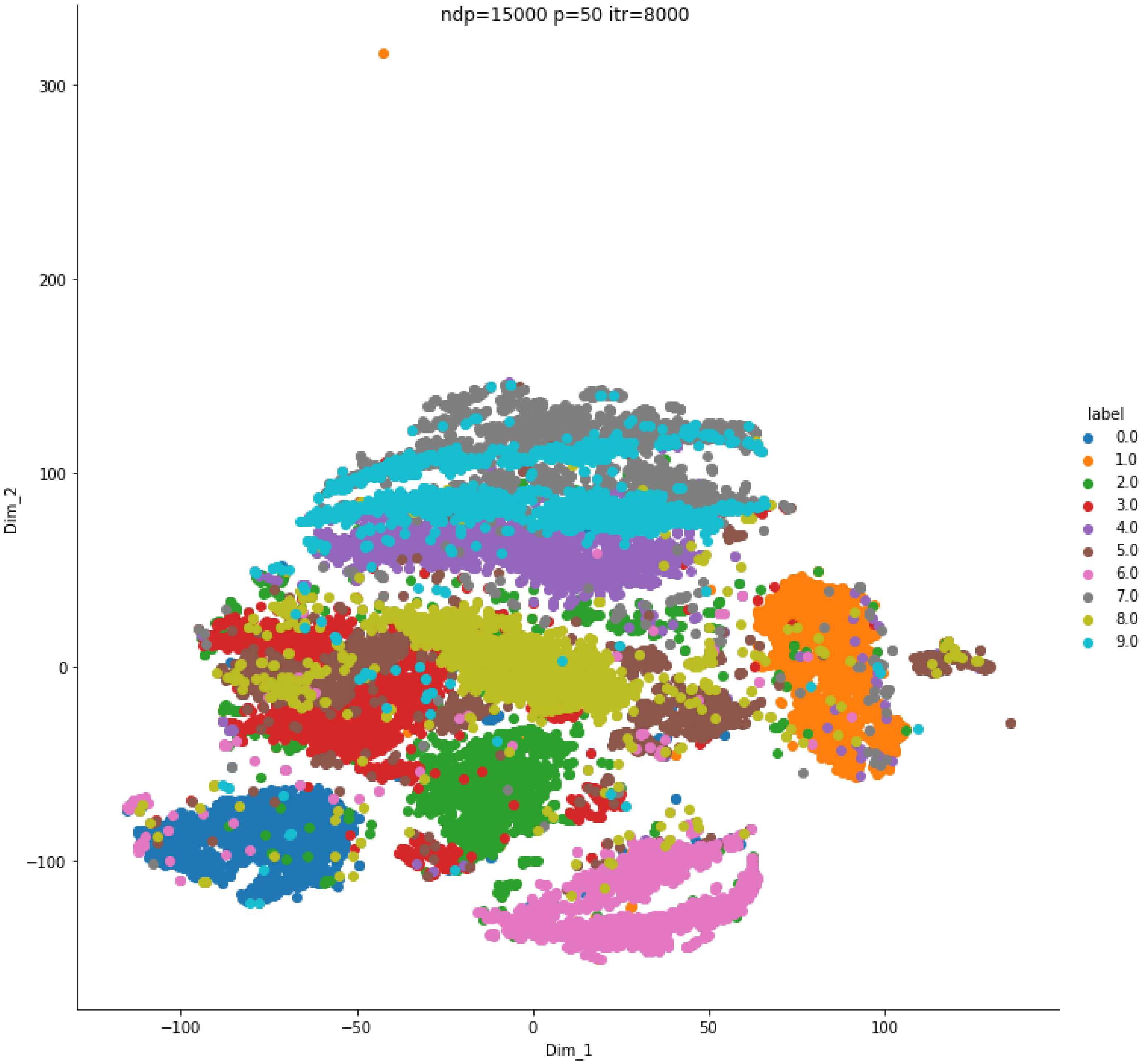

ndp=15000 p=50 itr=3000
200
150
100
50
0
−50
−100
Dim_2
−100
−50
0
50
100
Dim_1
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0

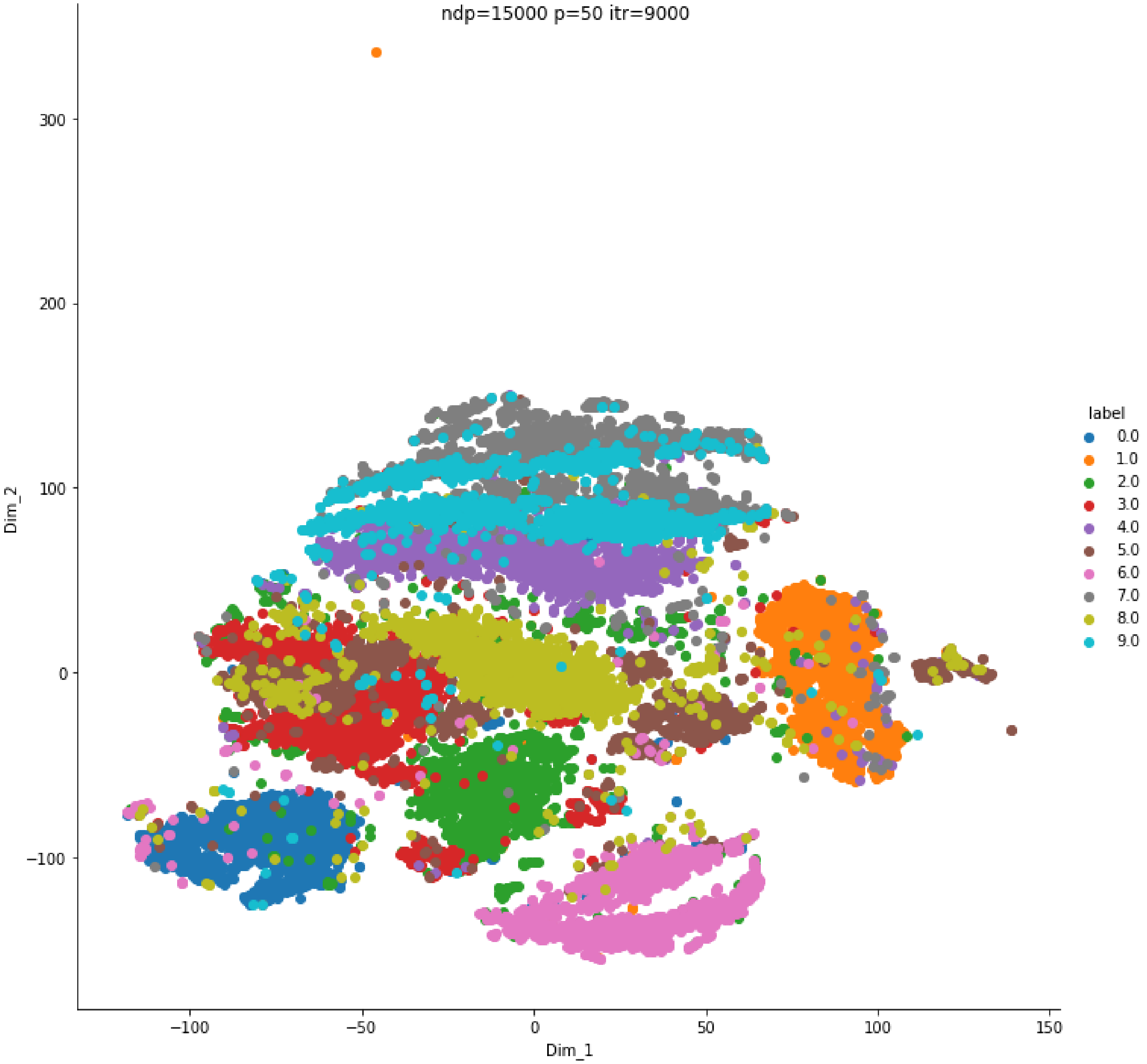

ndp=15000 p=50 itr=4000
Dim_2
Dim_1
200
150
100
50
0
−50
−100
−150
−100
−50
0
50
100
label
● 0.0
● 1.0
● 2.0
● 3.0
● 4.0
● 5.0
● 6.0
● 7.0
● 8.0
● 9.0

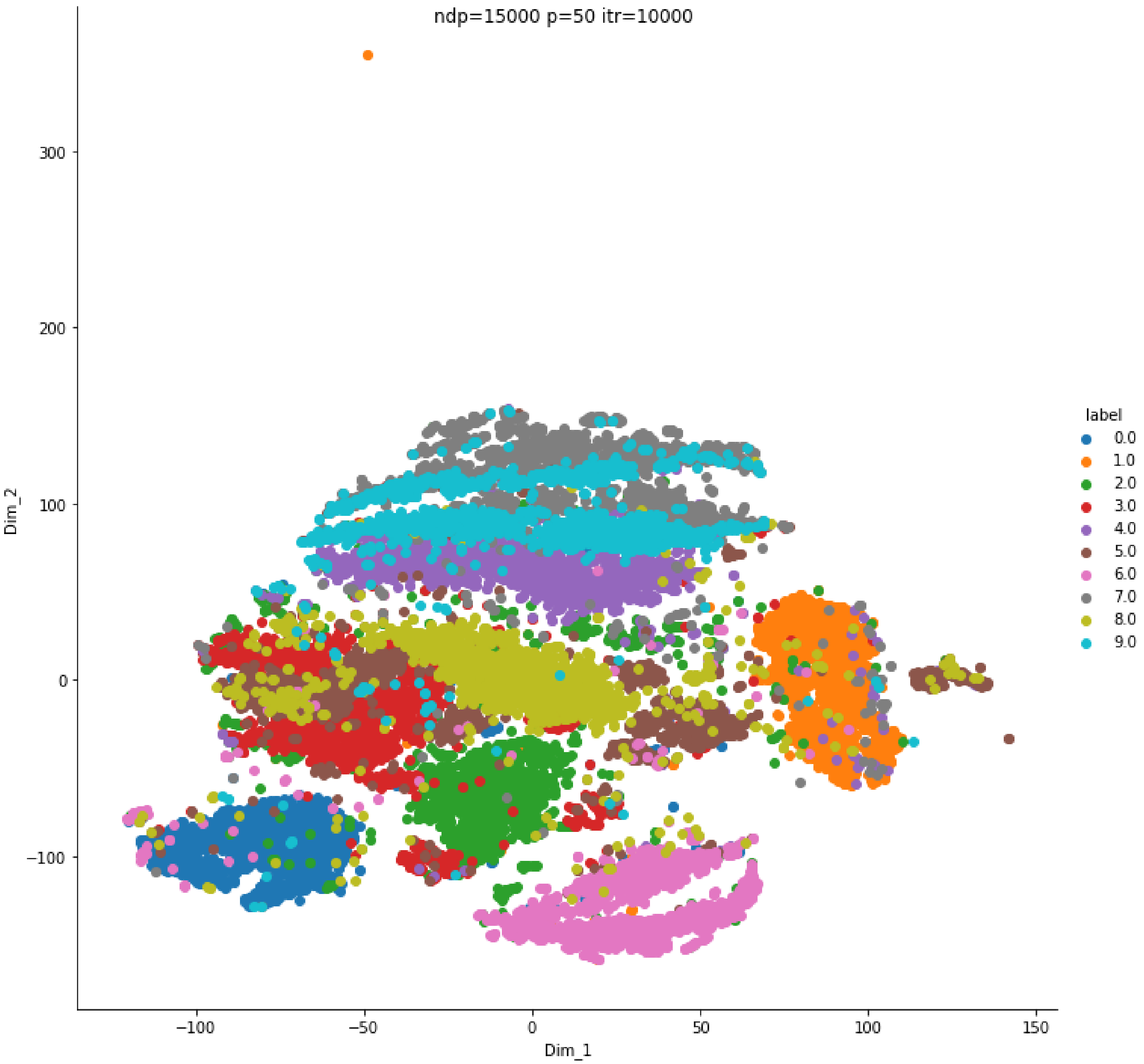

ndp=15000 p=50 itr=5000
250
200
150
100
50
0
−50
−100
−150
Dim_2
−100
−50
0
50
100
Dim_1
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0


ndp=15000 p=50 itr=6000
Dim_2
Dim_1
200
100
0
−100
−100
−50
0
50
100
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0


ndp=15000 p=50 itr=7000
300
200
100
0
−100
Dim_2
−100
−50
0
50
100
Dim_1
label
● 0.0
● 1.0
● 2.0
● 3.0
● 4.0
● 5.0
● 6.0
● 7.0
● 8.0
● 9.0


ndp=15000 p=50 itr=8000
300
200
100
0
−100
Dim_2
−100
−50
0
50
100
Dim_1
label
● 0.0
● 1.0
● 2.0
● 3.0
● 4.0
● 5.0
● 6.0
● 7.0
● 8.0
● 9.0


ndp=15000 p=50 itr=9000
300
200
100
0
−100
Dim_2
−100
−50
0
50
100
150
Dim_1
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0



1.2 Training Size - 42000 (All)

```
In [6]: # Taking 42000 images for training
        training_size = 42000

        d_train_labels = d_labels_all.head(training_size)
        d_train_data = d_data_all.head(training_size)
        print('Shape of Training Data {0}, Label {1}'.format(d_train_data.shape, d_train_labels.shape) )

        # standardize the data
        standardized_data = StandardScaler().fit_transform(d_train_data.astype(np.float64))
        standardized_data.shape
```

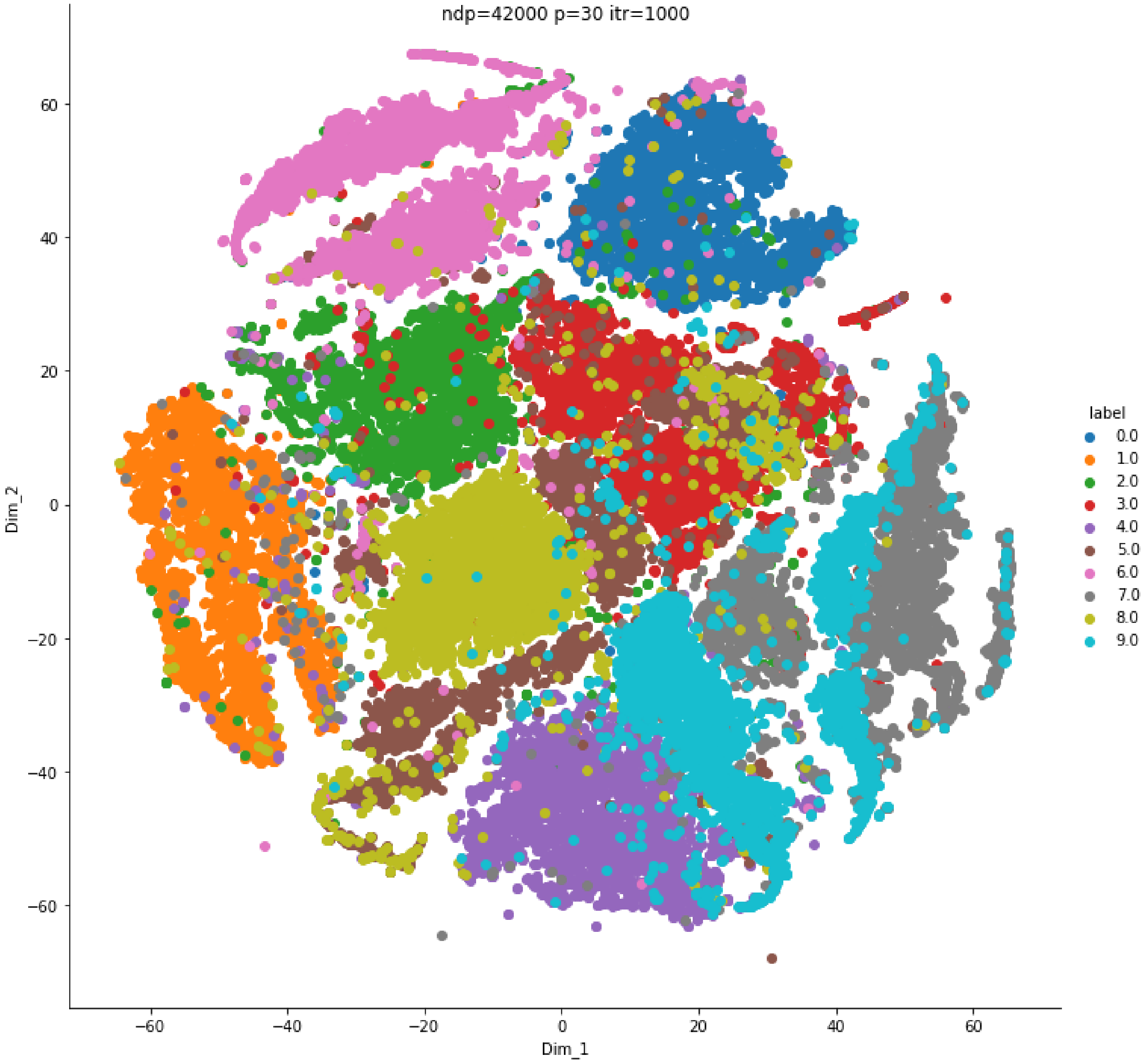
```
Shape of Training Data (42000, 784), Label (42000,)
```

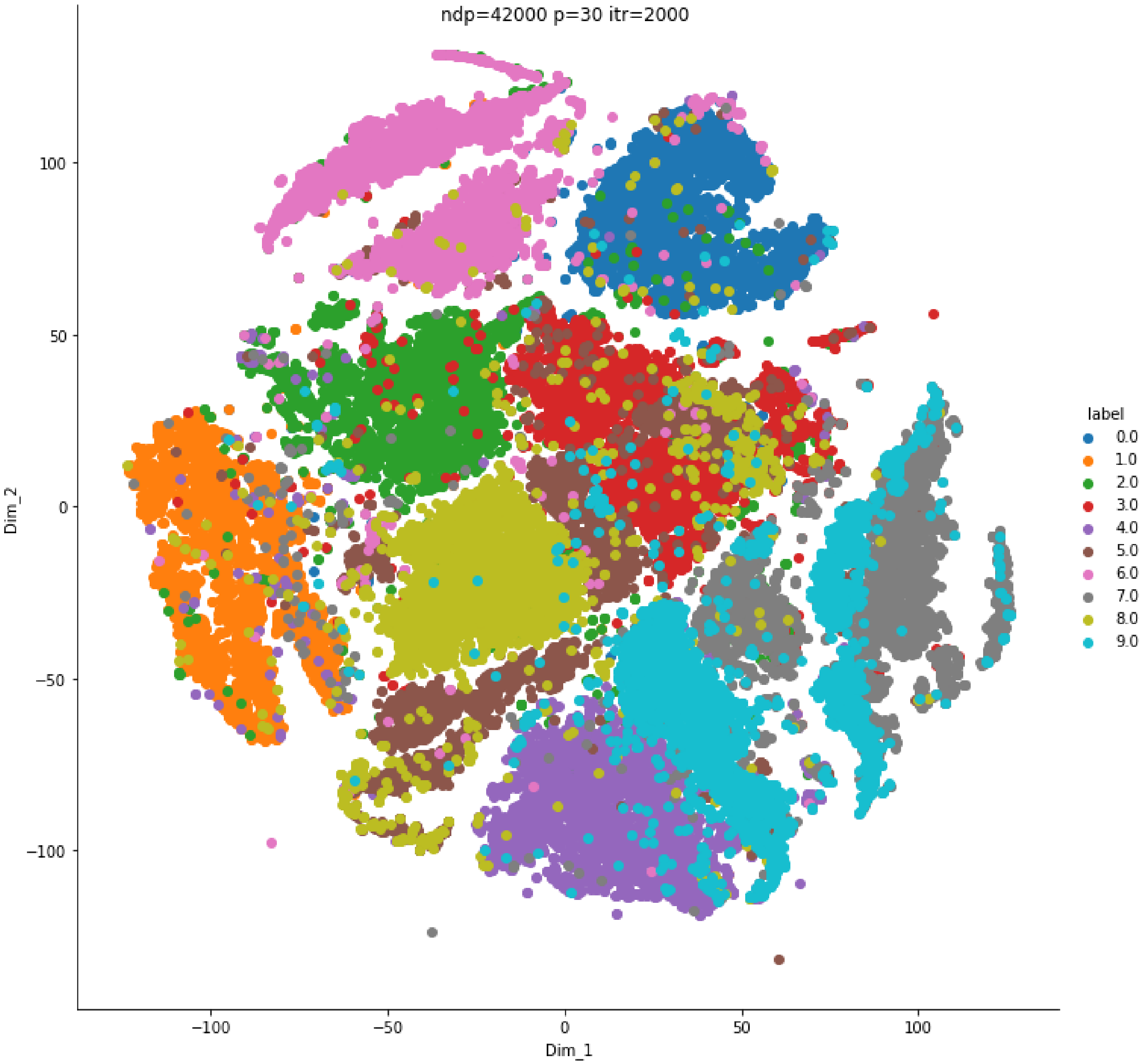
```
Out[6]: (42000, 784)
```

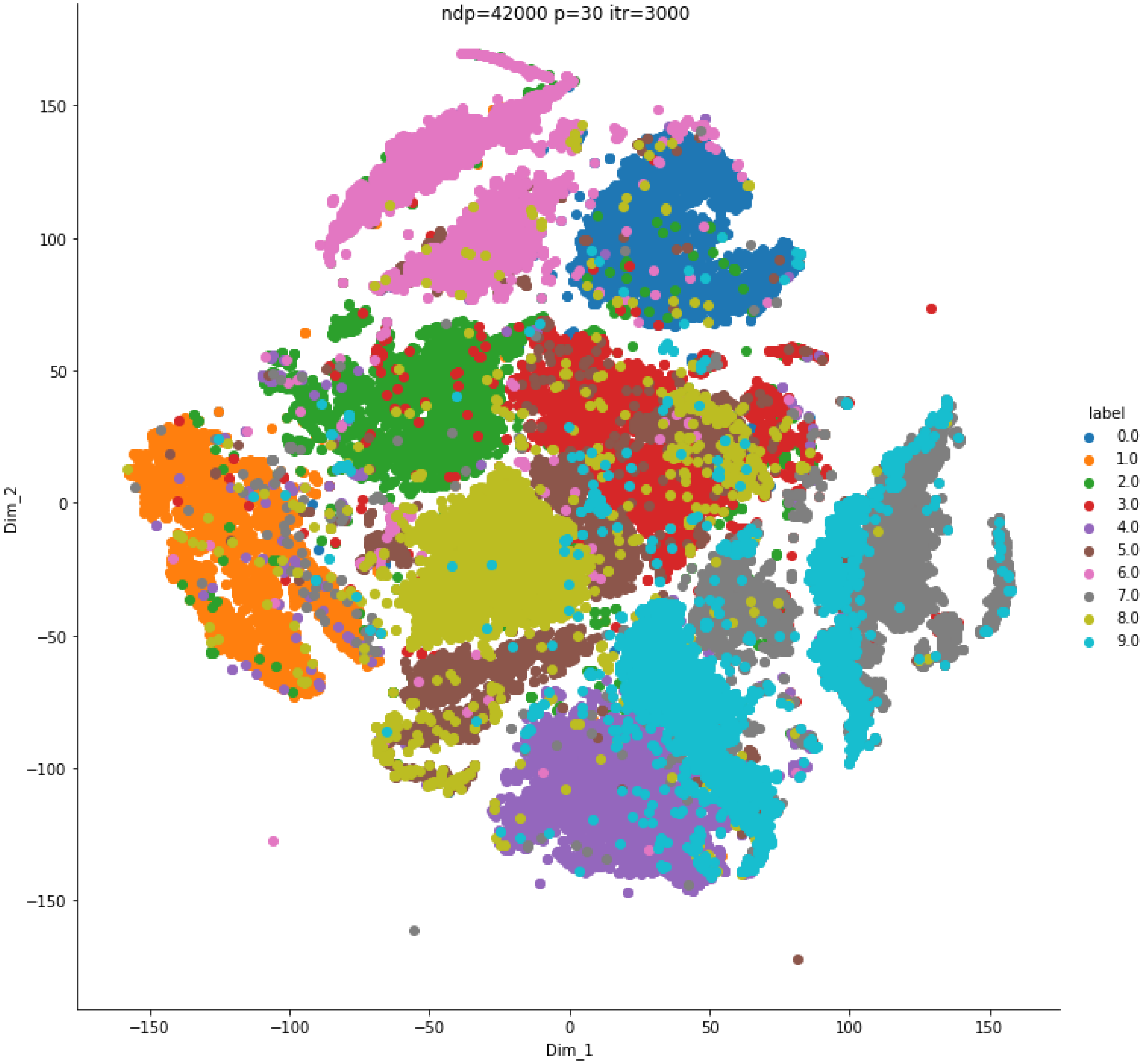
1.2.1 t-SNE over 42000 data points (All)

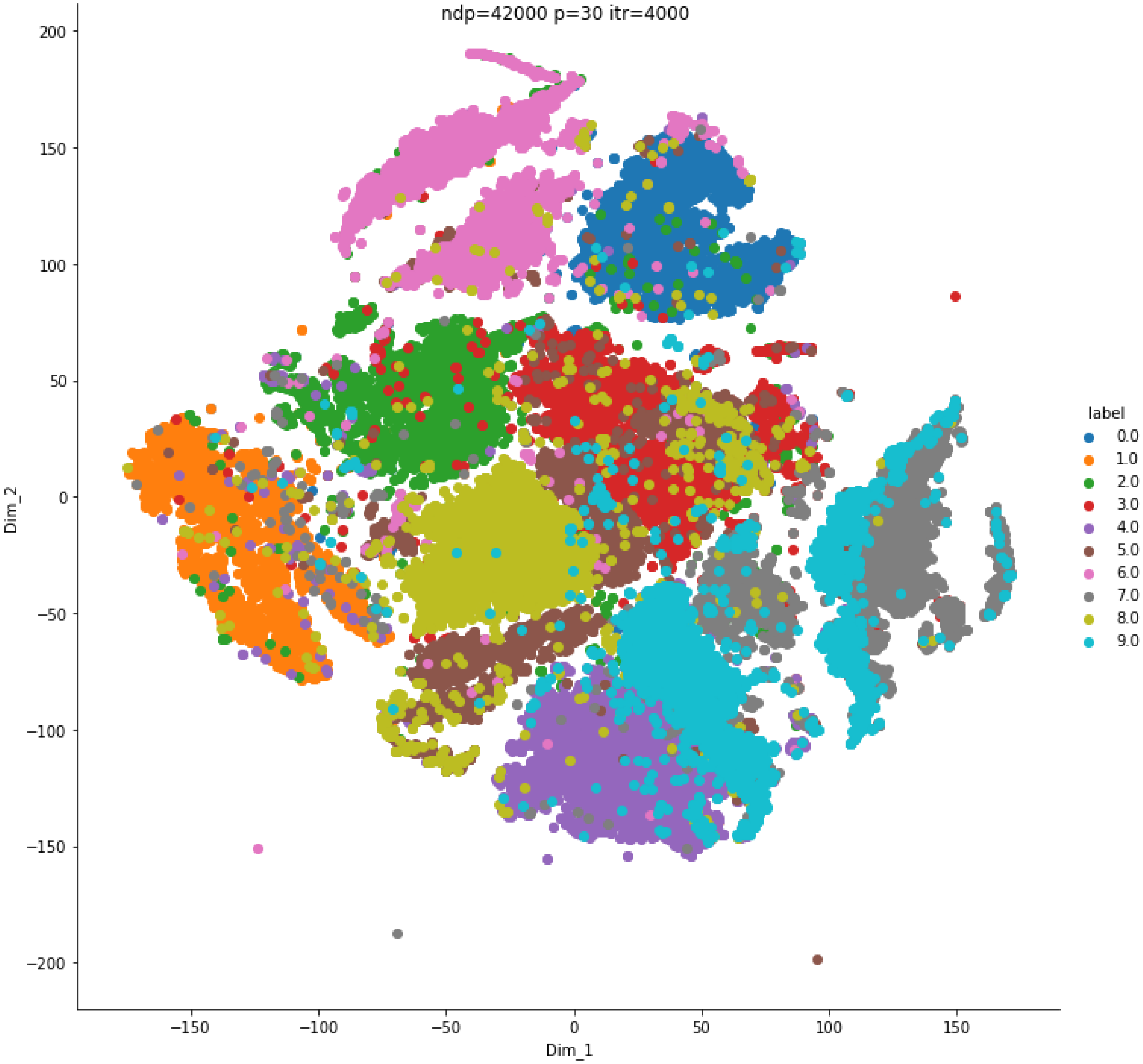
```
In [7]: genTSNEGif(standardized_data, training_size, 30, range(1000,10001,1000), 't_42000_d_45000_p_30')
```

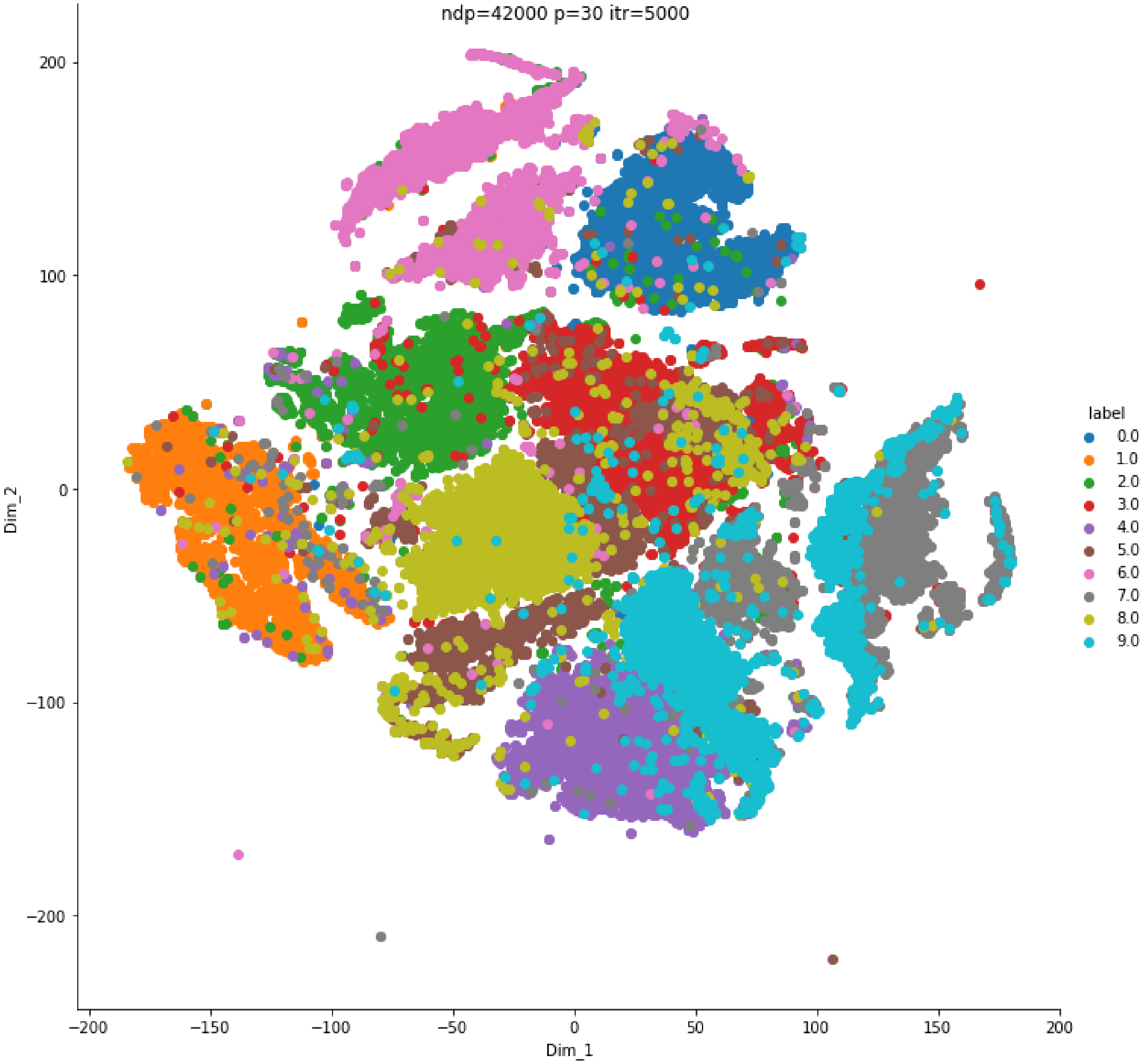
```
No.Of Data Points - 42000, Perplexity - 30, Iterations - range(1000, 10001, 1000), ImageName - t_42000_d_45000_p_30
ndp=42000 p=30 itr=1000 ==> t-SNE done! Time elapsed: 2545.7131152153015 seconds
ndp=42000 p=30 itr=2000 ==> t-SNE done! Time elapsed: 3017.718147754669 seconds
ndp=42000 p=30 itr=3000 ==> t-SNE done! Time elapsed: 3508.6030945777893 seconds
ndp=42000 p=30 itr=4000 ==> t-SNE done! Time elapsed: 4017.4480690956116 seconds
ndp=42000 p=30 itr=5000 ==> t-SNE done! Time elapsed: 4526.589033126831 seconds
ndp=42000 p=30 itr=6000 ==> t-SNE done! Time elapsed: 5056.142894983292 seconds
ndp=42000 p=30 itr=7000 ==> t-SNE done! Time elapsed: 5582.91085767746 seconds
ndp=42000 p=30 itr=8000 ==> t-SNE done! Time elapsed: 6129.846672296524 seconds
ndp=42000 p=30 itr=9000 ==> t-SNE done! Time elapsed: 6672.509294986725 seconds
ndp=42000 p=30 itr=10000 ==> t-SNE done! Time elapsed: 7246.688520908356 seconds
```

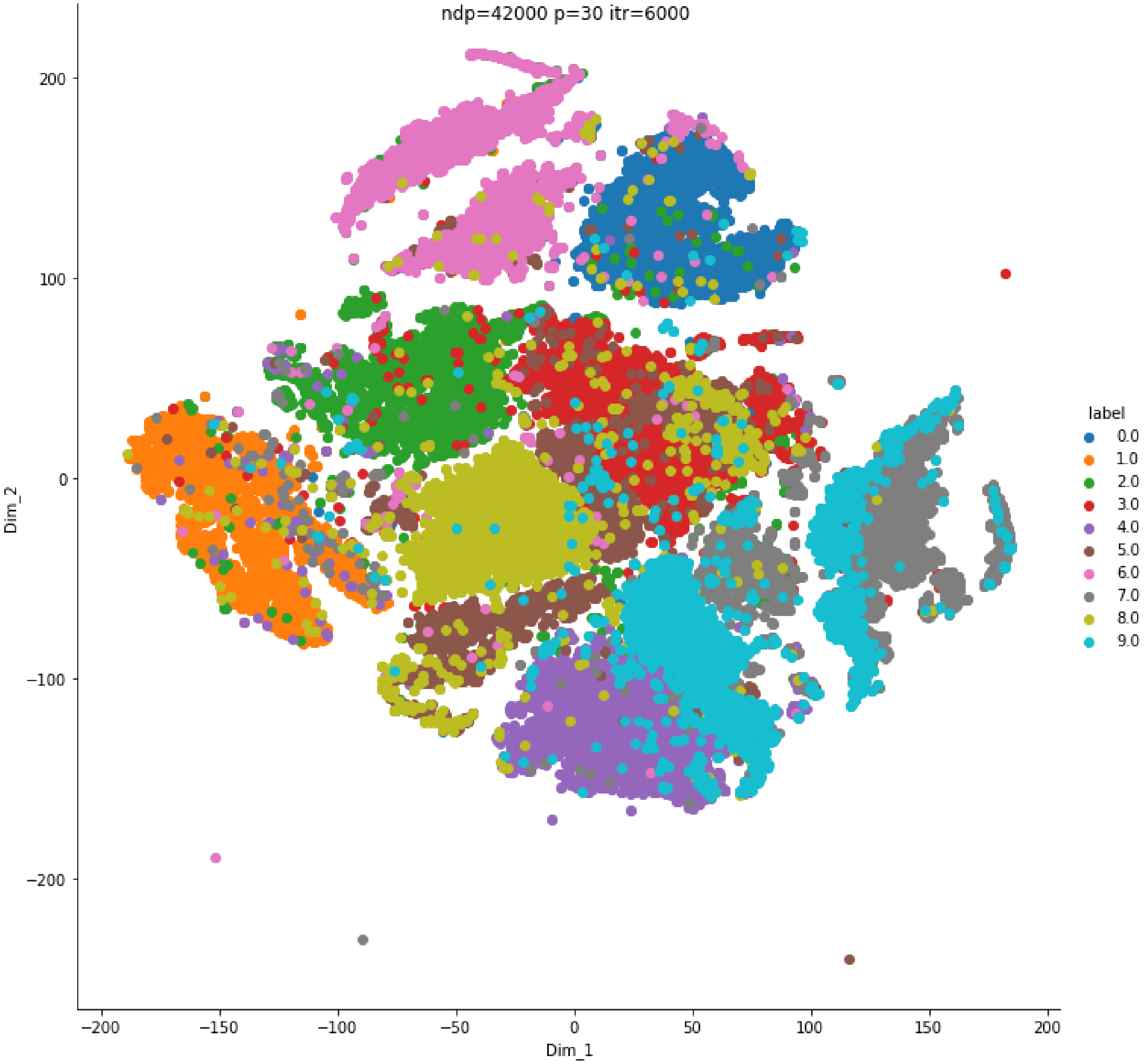


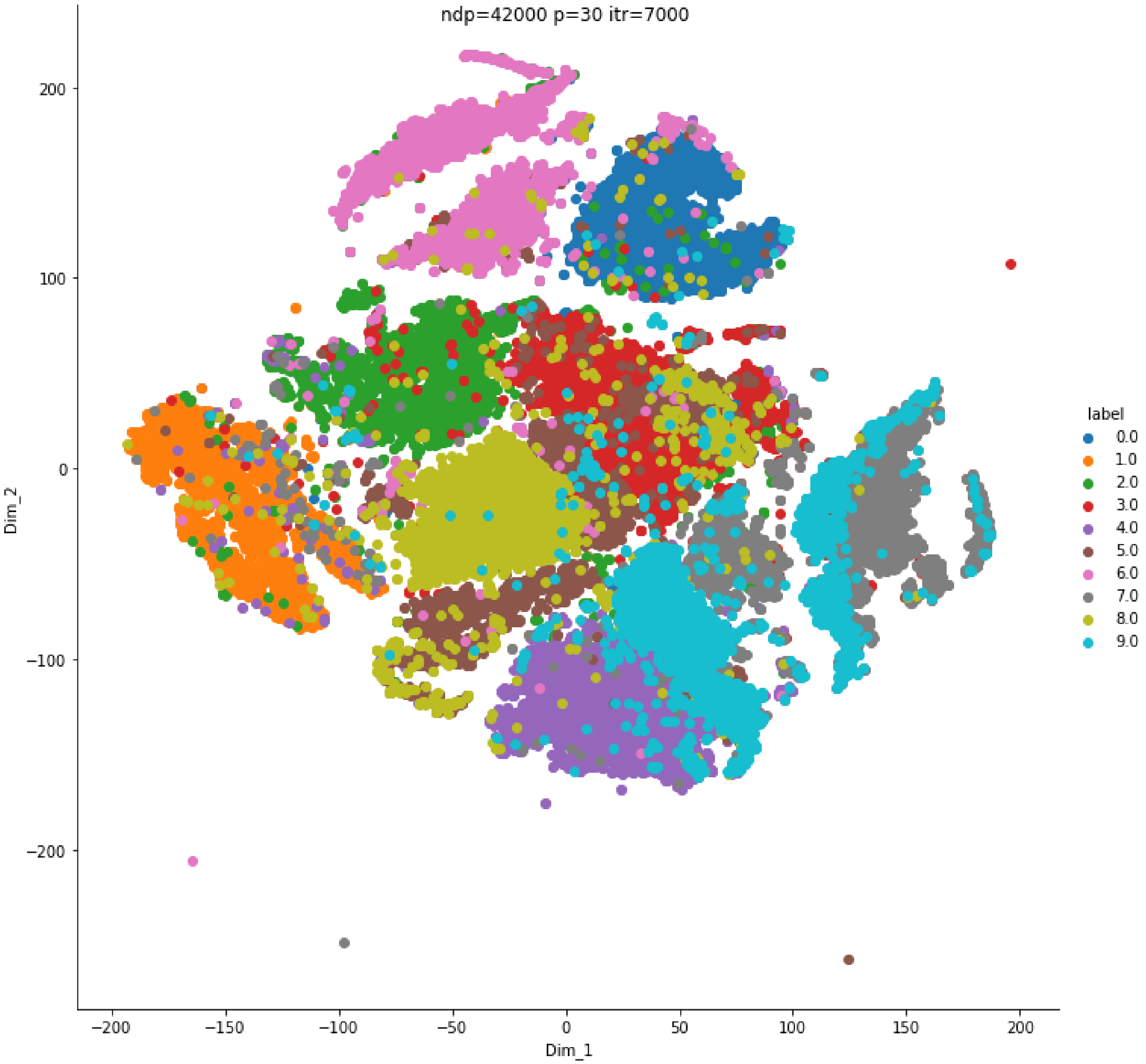

ndp=42000 p=30 itr=2000
Dim_2
100
50
0
−50
−100
Dim_1
−100
−50
0
50
100
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0

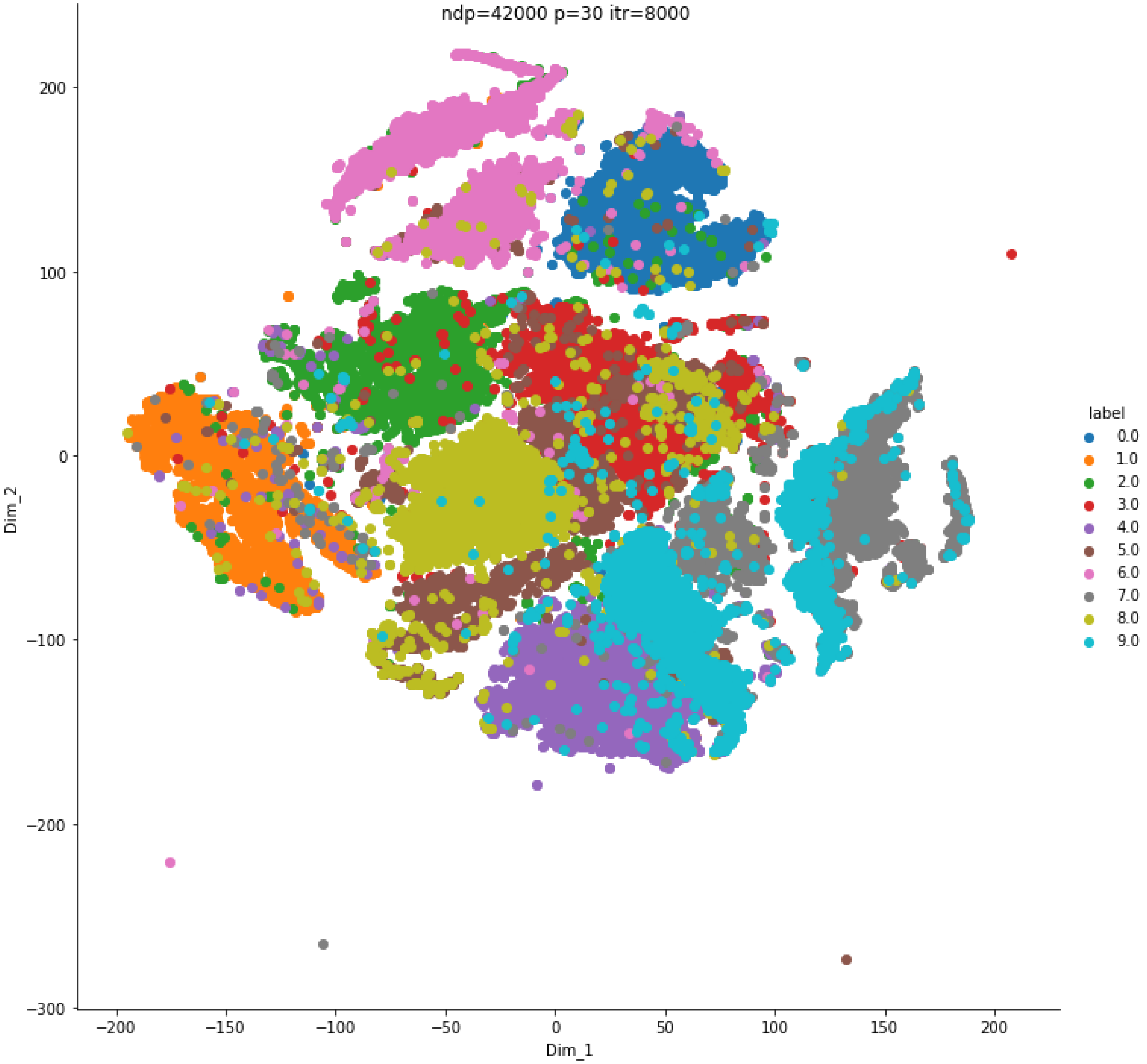

ndp=42000 p=30 itr=3000
Dim_2
Dim_1
150
100
50
0
−50
−100
−150
−150
−100
−50
0
50
100
150
label
● 0.0
● 1.0
● 2.0
● 3.0
● 4.0
● 5.0
● 6.0
● 7.0
● 8.0
● 9.0

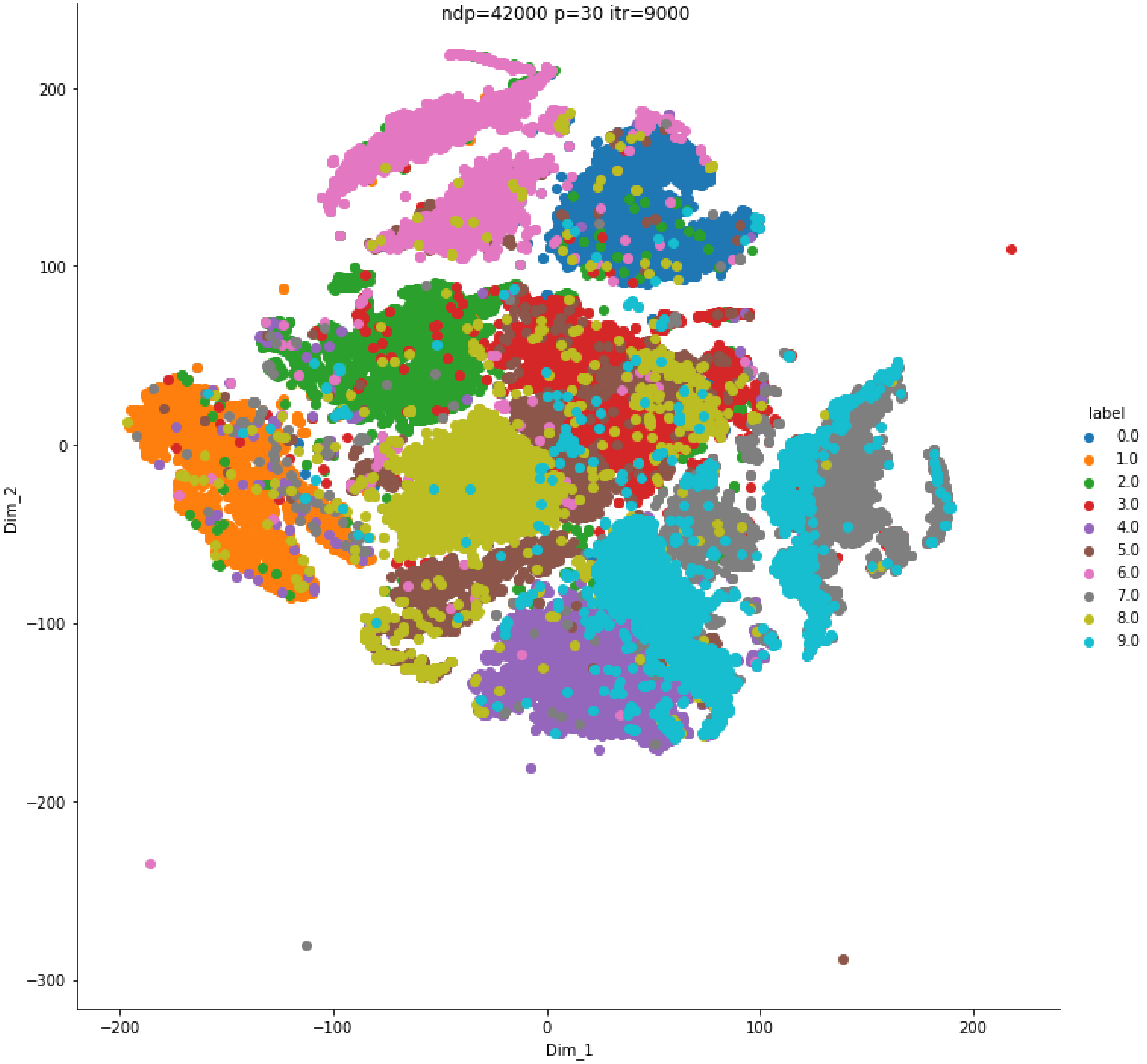

ndp=42000 p=30 itr=4000
Dim_2
200
150
100
50
0
−50
−100
−150
−200
Dim_1
−150
−100
−50
0
50
100
150
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0

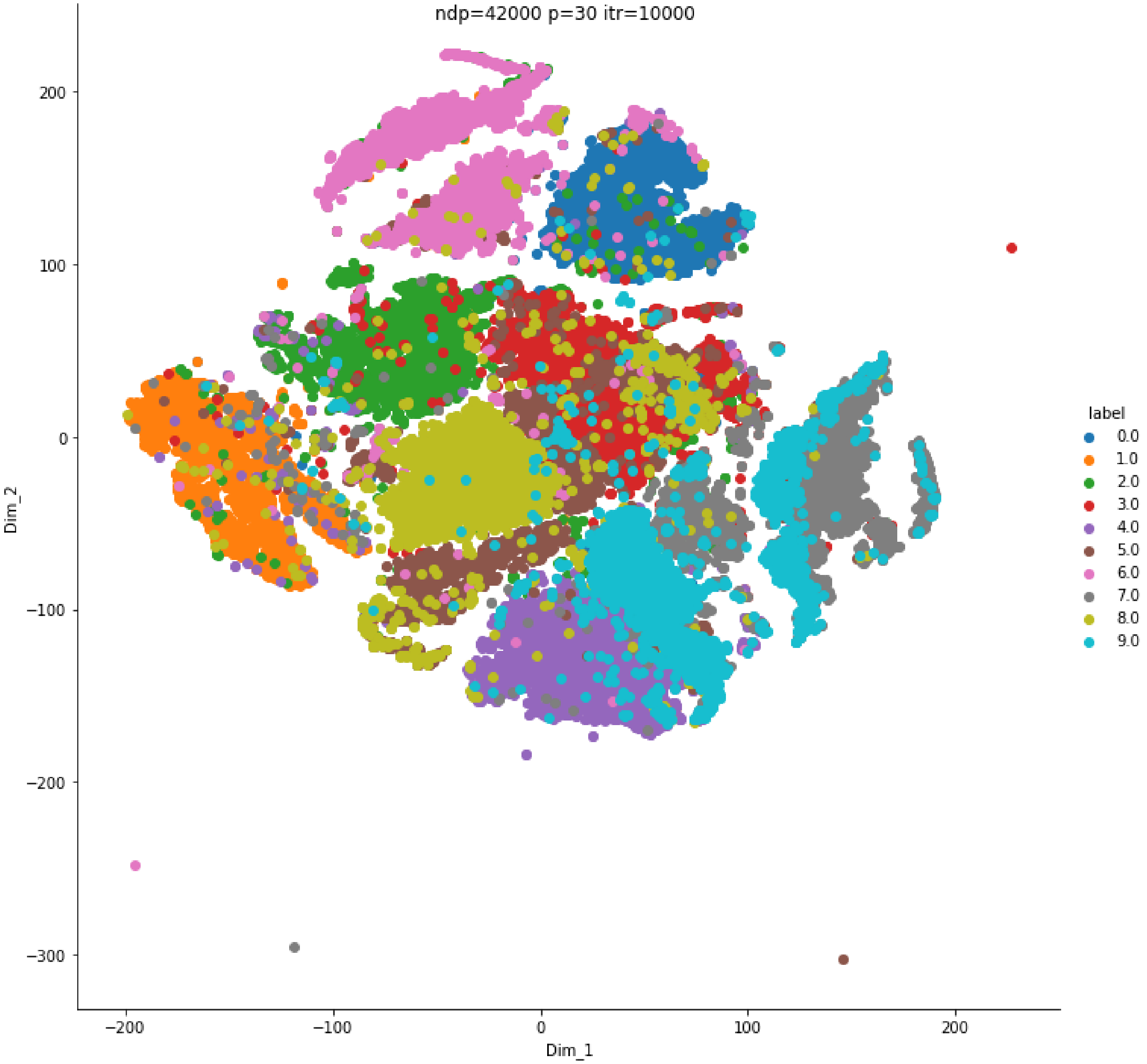

ndp=42000 p=30 itr=5000
Dim_2
Dim_1
200
100
0
−100
−200
−200
−150
−100
−50
0
50
100
150
200
label
● 0.0
● 1.0
● 2.0
● 3.0
● 4.0
● 5.0
● 6.0
● 7.0
● 8.0
● 9.0


ndp=42000 p=30 itr=6000
Dim_2
Dim_1
200
100
0
−100
−200
−200
−150
−100
−50
0
50
100
150
200
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0


ndp=42000 p=30 itr=7000
200
100
0
−100
−200
Dim_2
−200
−150
−100
−50
0
50
100
150
200
Dim_1
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0


ndp=42000 p=30 itr=8000
Dim_2
Dim_1
200
100
0
−100
−200
−300
−200
−150
−100
−50
0
50
100
150
200
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0


ndp=42000 p=30 itr=9000
Dim_2
Dim_1
200
100
0
−100
−200
−300
−200
−100
0
100
200
label
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0



```
In [ ]: genTSNEGif(standardized_data, training_size, 40, range(1000,5001,1000), 't_42000_d_45000_p_40')
```

```
No.Of Data Points - 42000, Perplexity - 40, Iterations - range(1000, 5001, 1000), ImageName - t_42000_d_45000_p_40
ndp=42000 p=40 itr=1000 ==> t-SNE done! Time elapsed: 2630.960303544998 seconds
ndp=42000 p=40 itr=2000 ==> t-SNE done! Time elapsed: 3065.3994250297546 seconds
ndp=42000 p=40 itr=3000 ==> t-SNE done! Time elapsed: 3598.724067926407 seconds
ndp=42000 p=40 itr=4000 ==> t-SNE done! Time elapsed: 4125.029971837997 seconds
ndp=42000 p=40 itr=5000 ==> t-SNE done! Time elapsed: 4683.721975326538 seconds
```

```
In [ ]: genTSNEGif(standardized_data, training_size, 50, range(1000,5001,1000), 't_42000_d_45000_p_50')
```

2 Observation

- With Perplexity 30, after 3000 iterations, image becomes stable