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(http://cocl.us/pytorch_link_top)

Linear Regression 1D: Training Two Parameter Mini-Batch Gradient Decent

Table of Contents

In this Lab, you will practice training a model by using Mini-Batch Gradient Descent.

Estimated Time Needed: **30 min**
</div>

Preparation

We'll need the following libraries:

In [1]:

```
# Import the libraries we need for this lab

import numpy as np
import matplotlib.pyplot as plt
from mpl_toolkits import mplot3d
```

The class `plot_error_surfaces` is just to help you visualize the data space and the parameter space during training and has nothing to do with PyTorch.

In [2]:

```
# The class for plotting the diagrams

class plot_error_surfaces(object):

    # Constructor
    def __init__(self, w_range, b_range, X, Y, n_samples = 30, go = True):
        W = np.linspace(-w_range, w_range, n_samples)
        B = np.linspace(-b_range, b_range, n_samples)
        w, b = np.meshgrid(W, B)
        Z = np.zeros((30, 30))
        count1 = 0
        self.y = Y.numpy()
        self.x = X.numpy()
        for w1, b1 in zip(w, b):
            count2 = 0
            for w2, b2 in zip(w1, b1):
                Z[count1, count2] = np.mean((self.y - w2 * self.x + b2) ** 2)
                count2 += 1
            count1 += 1
        self.Z = Z
        self.w = w
        self.b = b
        self.W = []
        self.B = []
        self.LOSS = []
        self.n = 0
        if go == True:
            plt.figure()
            plt.figure(figsize = (7.5, 5))
            plt.axes(projection = '3d').plot_surface(self.w, self.b, self.Z, rstrid
e = 1, cstride = 1, cmap = 'viridis', edgecolor = 'none')
            plt.title('Loss Surface')
            plt.xlabel('w')
            plt.ylabel('b')
            plt.show()
            plt.figure()
            plt.title('Loss Surface Contour')
            plt.xlabel('w')
            plt.ylabel('b')
            plt.contour(self.w, self.b, self.Z)
            plt.show()

     # Setter
    def set_para_loss(self, W, B, loss):
        self.n = self.n + 1
        self.W.append(W)
        self.B.append(B)
        self.LOSS.append(loss)

    # Plot diagram
    def final_plot(self):
        ax = plt.axes(projection = '3d')
        ax.plot_wireframe(self.w, self.b, self.Z)
        ax.scatter(self.W, self.B, self.LOSS, c = 'r', marker = 'x', s = 200, alpha
= 1)
```

```
        plt.figure()
        plt.contour(self.w, self.b, self.Z)
        plt.scatter(self.W, self.B, c = 'r', marker = 'x')
        plt.xlabel('w')
        plt.ylabel('b')
        plt.show()

    # Plot diagram
    def plot_ps(self):
        plt.subplot(121)
        plt.ylim()
        plt.plot(self.x, self.y, 'ro', label = "training points")
        plt.plot(self.x, self.W[-1] * self.x + self.B[-1], label = "estimated line"
)
        plt.xlabel('x')
        plt.ylabel('y')
        plt.title('Data Space Iteration: '+ str(self.n))
        plt.subplot(122)
        plt.contour(self.w, self.b, self.Z)
        plt.scatter(self.W, self.B, c = 'r', marker = 'x')
        plt.title('Loss Surface Contour')
        plt.xlabel('w')
        plt.ylabel('b')
        plt.show()
```

Make Some Data

Import PyTorch and set random seed:

In [3]:

```
# Import PyTorch library

import torch
torch.manual_seed(1)
```

Out[3]:

```
<torch._C.Generator at 0x7f23772dc050>
```

Generate values from -3 to 3 that create a line with a slope of 1 and a bias of -1. This is the line that you need to estimate. Add some noise to the data:

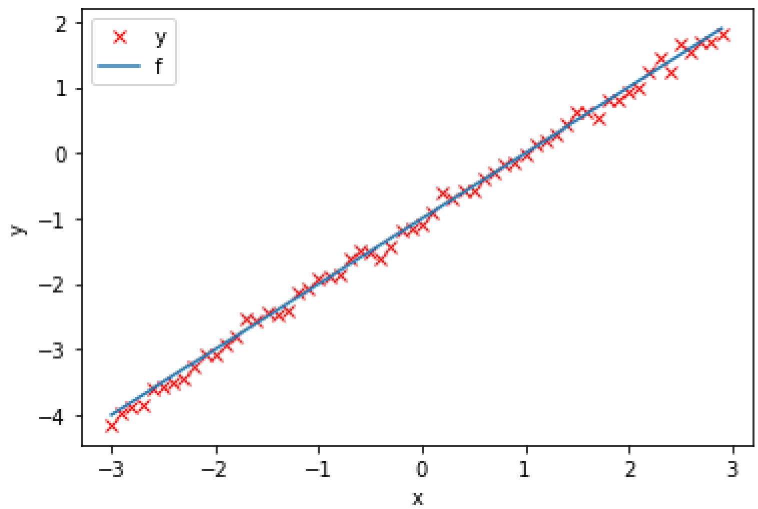
In [4]:

```
# Generate the data with noise and the line

X = torch.arange(-3, 3, 0.1).view(-1, 1)
f = 1 * X - 1
Y = f + 0.1 * torch.randn(X.size())
```

Plot the results:

In [5]:

```
# Plot the line and the data

plt.plot(X.numpy(), Y.numpy(), 'rx', label = 'y')
plt.plot(X.numpy(), f.numpy(), label = 'f')
plt.xlabel('x')
plt.ylabel('y')
plt.legend()
plt.show()
```



Create the Model and Cost Function (Total Loss)

Define the `forward` function:

In [6]:

```
# Define the prediction function

def forward(x):
    return w * x + b
```

Define the cost or criterion function:

In [7]:

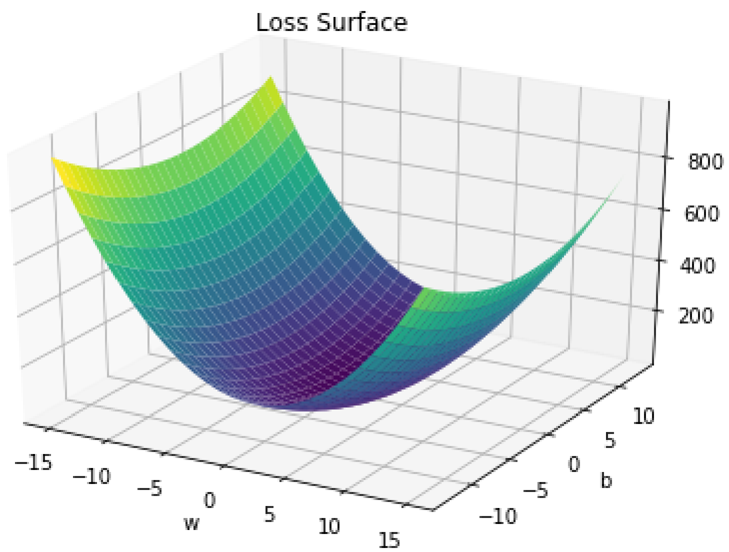
```
# Define the cost function

def criterion(yhat, y):
    return torch.mean((yhat - y) ** 2)
```

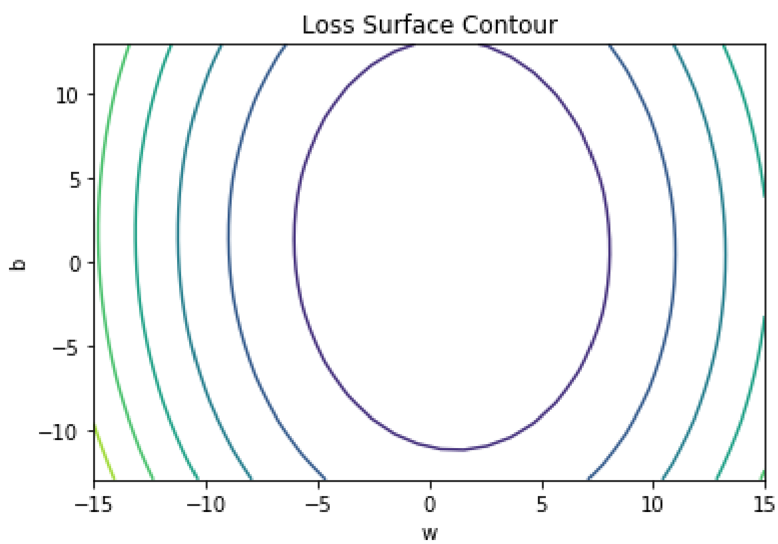
Create a `plot_error_surfaces` object to visualize the data space and the parameter space during training:

In [8]:

```
# Create a plot_error_surfaces object.

get_surface = plot_error_surfaces(15, 13, X, Y, 30)
```

```
<Figure size 432x288 with 0 Axes>
```





Train the Model: Batch Gradient Descent (BGD)

Define `train_model_BGD` function.

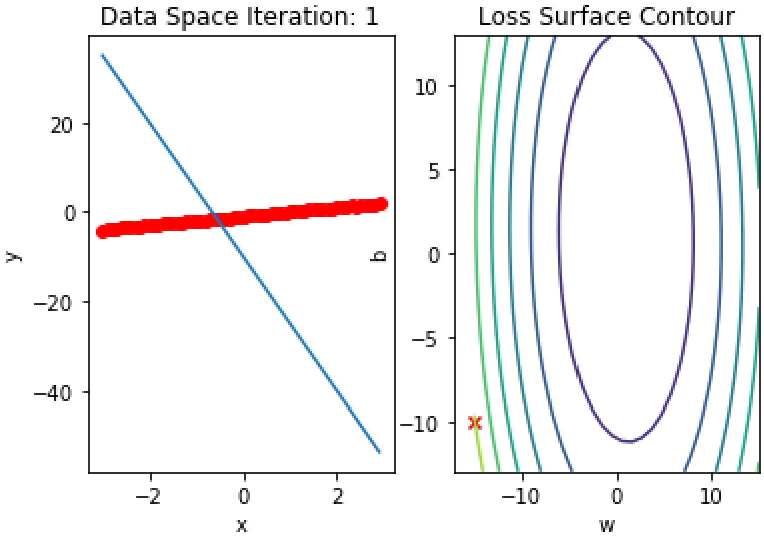
In [9]:

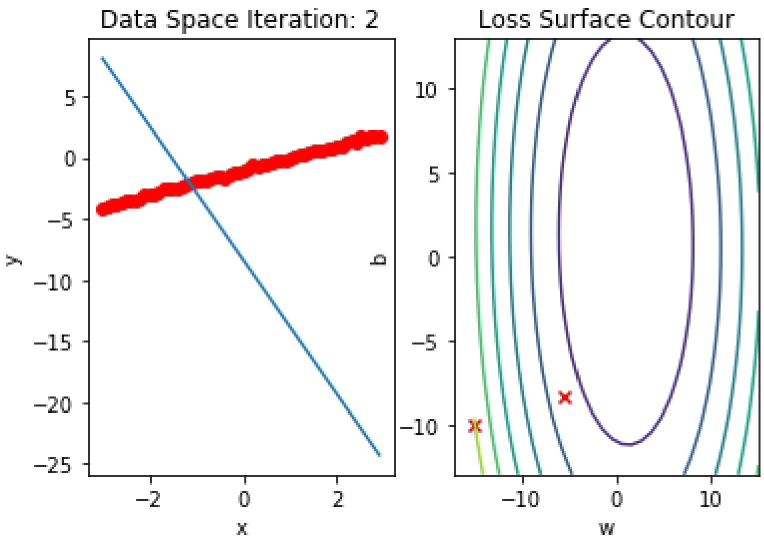
```
# Define the function for training model

w = torch.tensor(-15.0, requires_grad = True)
b = torch.tensor(-10.0, requires_grad = True)
lr = 0.1
LOSS_BGD = []

def train_model_BGD(epochs):
    for epoch in range(epochs):
        Yhat = forward(X)
        loss = criterion(Yhat, Y)
        LOSS_BGD.append(loss)
        get_surface.set_para_loss(w.data.tolist(), b.data.tolist(), loss.tolist())
        get_surface.plot_ps()
        loss.backward()
        w.data = w.data - lr * w.grad.data
        b.data = b.data - lr * b.grad.data
        w.grad.data.zero_()
        b.grad.data.zero_()
```

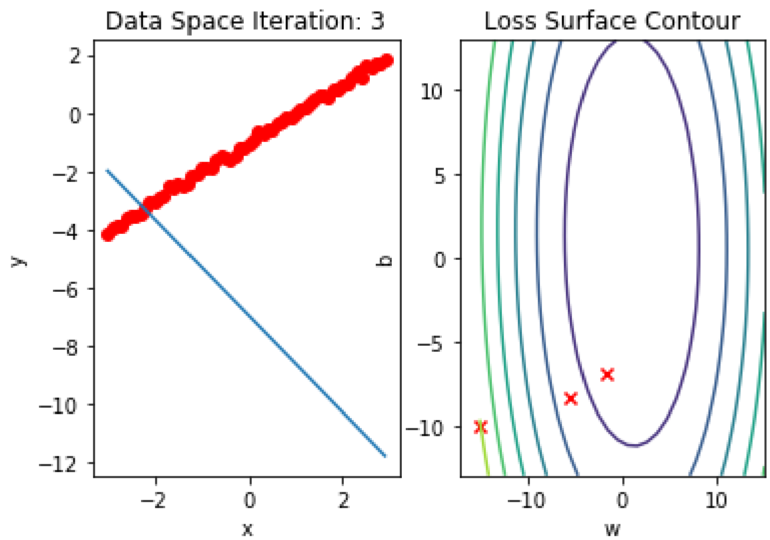
Run 10 epochs of batch gradient descent: **bug** data space is 1 iteration ahead of parameter space.

In [10]:

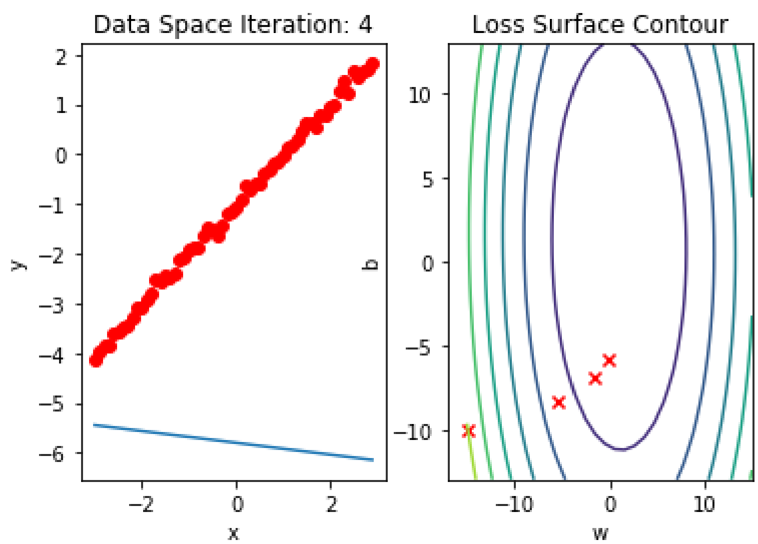
```
# Run train_model_BGD with 10 iterations

train_model_BGD(10)
```


Data Space Iteration: 1
Loss Surface Contour
y
x
b
w
20
0
−20
−40
−2
0
2
10
5
0
−5
−10
−10
0
10

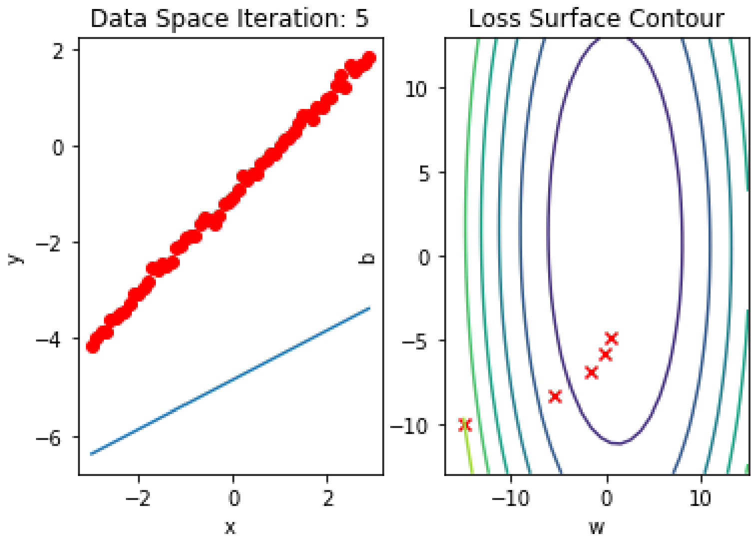

Data Space Iteration: 2
Loss Surface Contour
y
x
b
w
5
0
−5
−10
−15
−20
−25
−2
0
2
10
5
0
−5
−10
−10
0
10



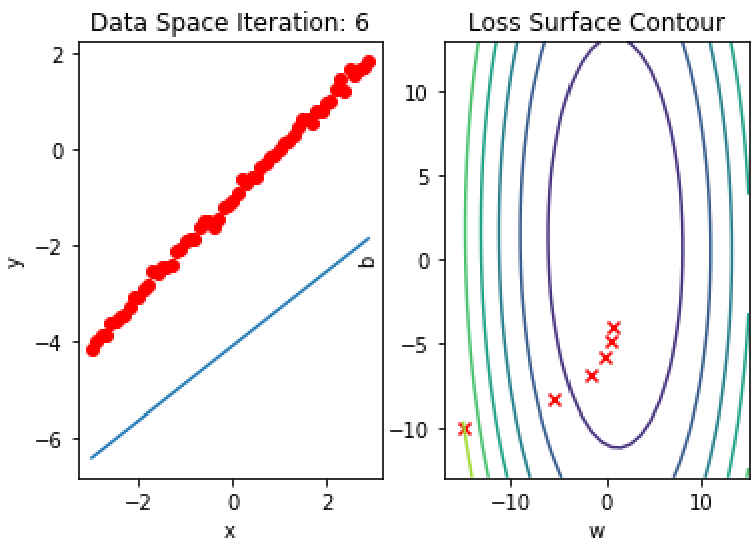
Data Space Iteration: 3
Loss Surface Contour
x
y
w
b



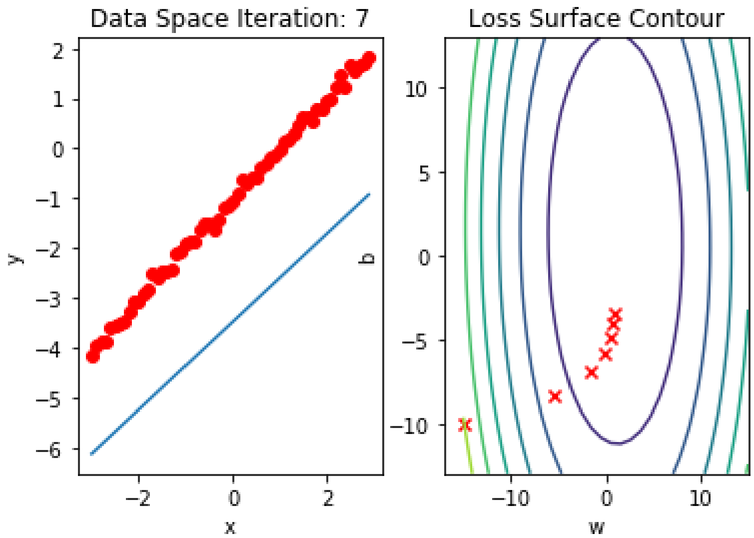
Data Space Iteration: 4
Loss Surface Contour
x
y
w
b

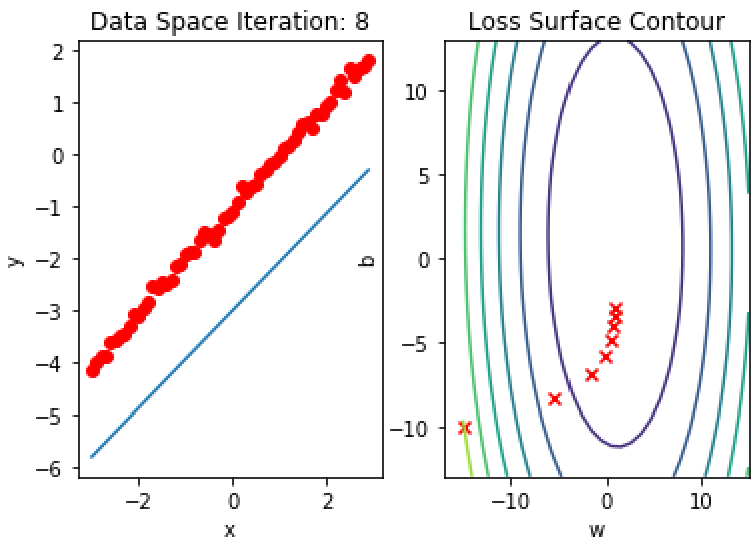


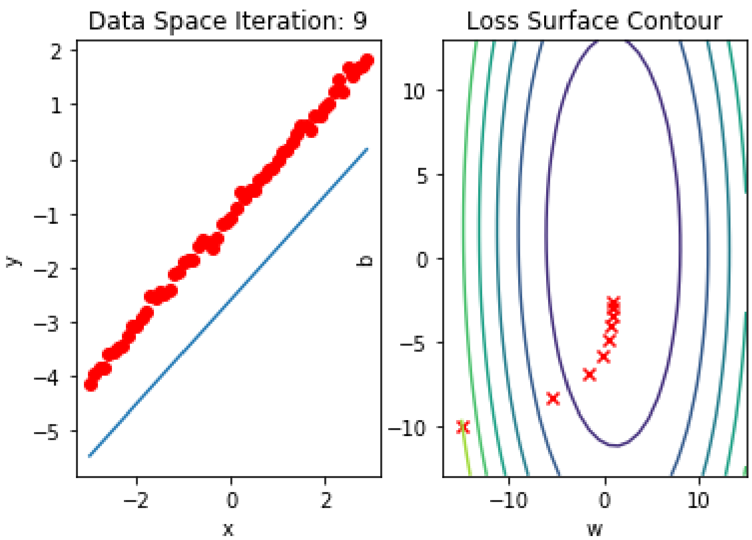
Data Space Iteration: 5
Loss Surface Contour
y
x
b
w

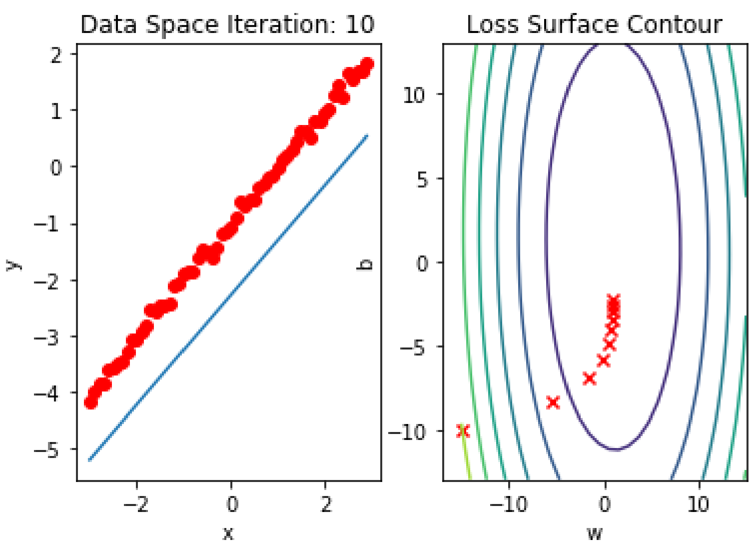


Data Space Iteration: 6
Loss Surface Contour
y
x
b
w


Data Space Iteration: 7
Loss Surface Contour
x
y
w
b


Data Space Iteration: 8
Loss Surface Contour
x
y
w
b





Stochastic Gradient Descent (SGD) with Dataset DataLoader

Create a `plot_error_surfaces` object to visualize the data space and the parameter space during training:

In [11]:

```
# Create a plot_error_surfaces object.

get_surface = plot_error_surfaces(15, 13, X, Y, 30, go = False)
```

Import `Dataset` and `DataLoader` libraries

In [12]:

```
# Import libraries

from torch.utils.data import Dataset, DataLoader
```

Create `Data` class

In [13]:

```
# Create class Data

class Data(Dataset):

    # Constructor
    def __init__(self):
        self.x = torch.arange(-3, 3, 0.1).view(-1, 1)
        self.y = 1 * X - 1
        self.len = self.x.shape[0]

    # Getter
    def __getitem__(self, index):
        return self.x[index], self.y[index]

    # Get length
    def __len__(self):
        return self.len
```

Create a dataset object and a dataloader object:

In [14]:

```
# Create Data object and DataLoader object

dataset = Data()
trainloader = DataLoader(dataset = dataset, batch_size = 1)
```

Define `train_model_SGD` function for training the model.

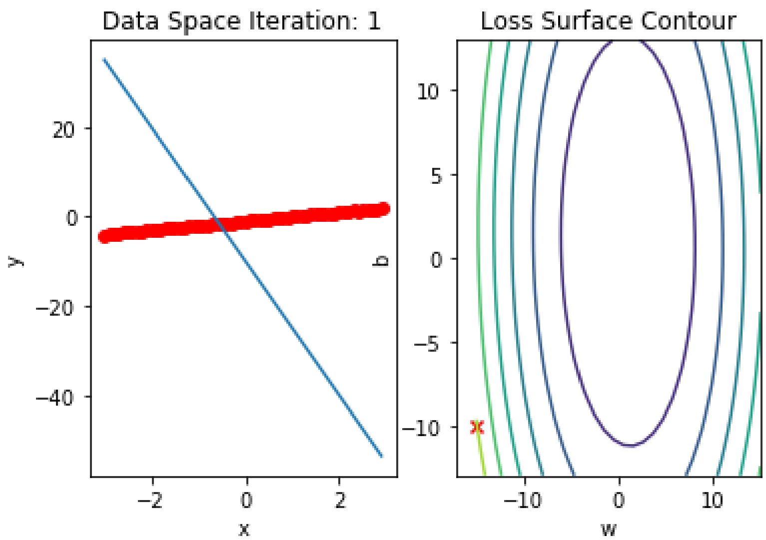
In [15]:

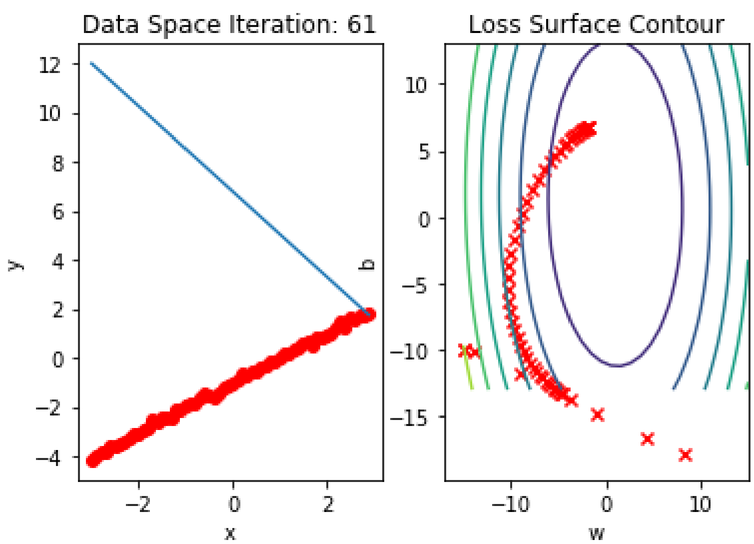
```
# Define train_model_SGD function

w = torch.tensor(-15.0, requires_grad = True)
b = torch.tensor(-10.0, requires_grad = True)
LOSS_SGD = []
lr = 0.1
def train_model_SGD(epochs):
    for epoch in range(epochs):
        Yhat = forward(X)
        get_surface.set_para_loss(w.data.tolist(), b.data.tolist(), criterion(Yhat,
Y).tolist())
        get_surface.plot_ps()
        LOSS_SGD.append(criterion(forward(X), Y).tolist())
        for x, y in trainloader:
            yhat = forward(x)
            loss = criterion(yhat, y)
            get_surface.set_para_loss(w.data.tolist(), b.data.tolist(), loss.tolist
())
            loss.backward()
            w.data = w.data - lr * w.grad.data
            b.data = b.data - lr * b.grad.data
            w.grad.data.zero_()
            b.grad.data.zero_()
        get_surface.plot_ps()
```

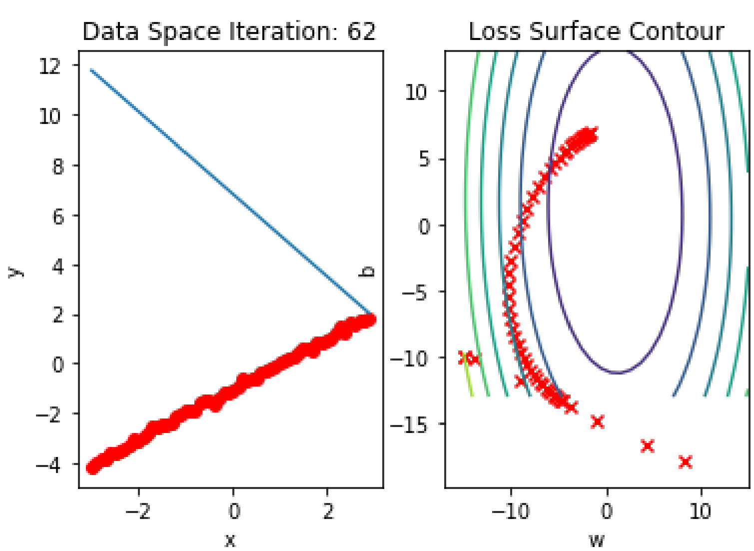
Run 10 epochs of stochastic gradient descent: **bug** data space is 1 iteration ahead of parameter space.

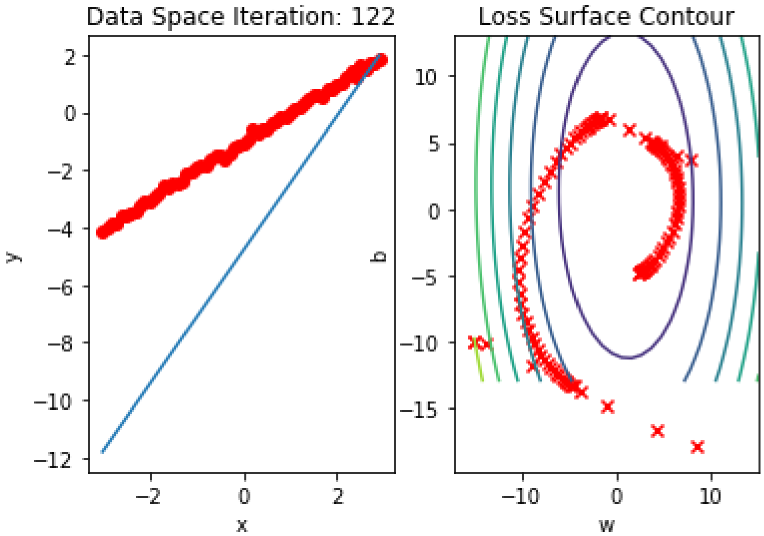
In [16]:

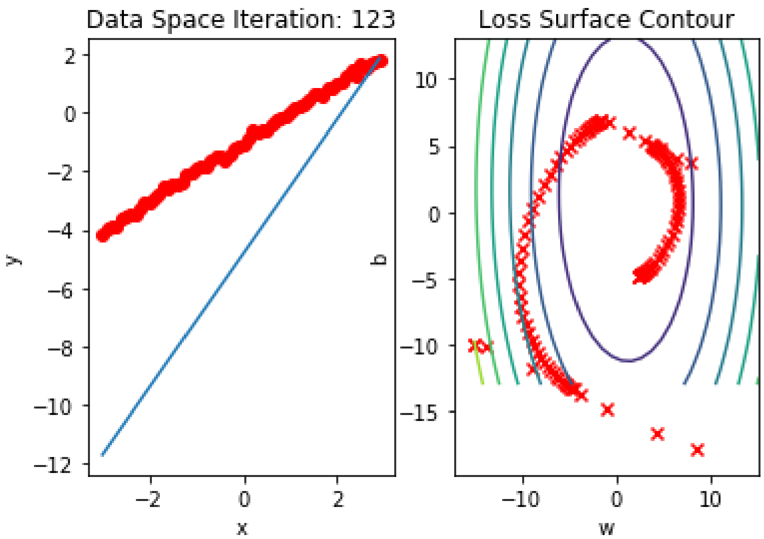
```
# Run train_model_SGD(iter) with 10 iterations

train_model_SGD(10)
```

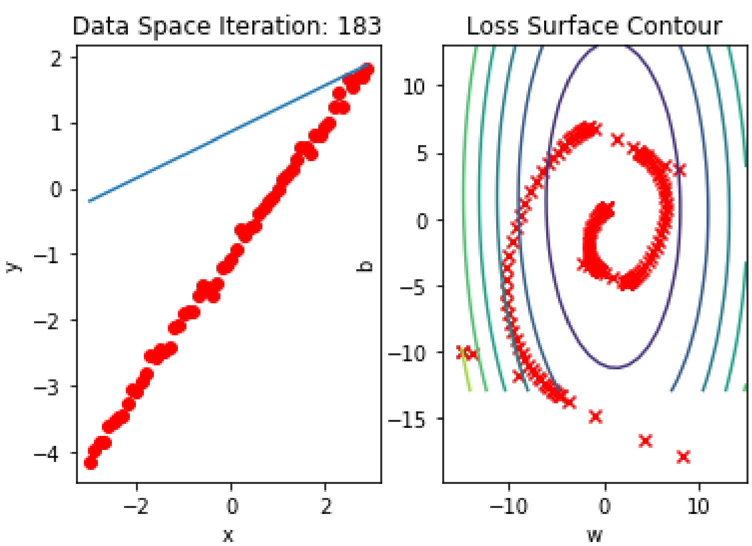

Data Space Iteration: 1
Loss Surface Contour
x
y
w
b

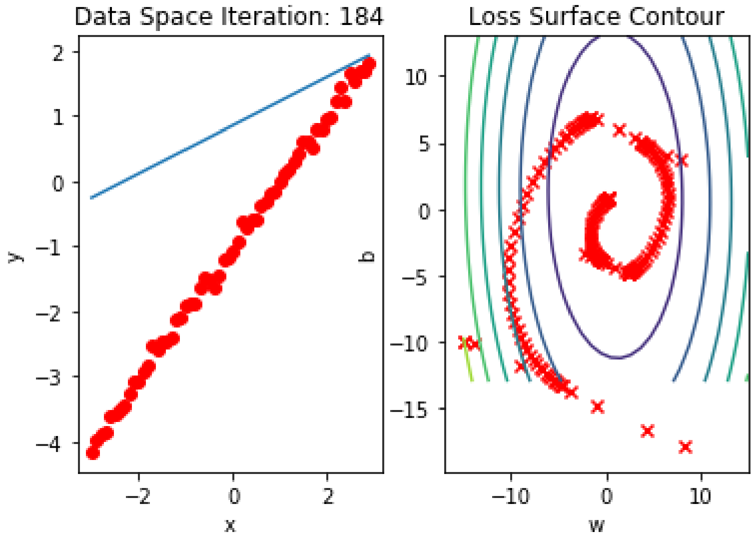

Data Space Iteration: 61
Loss Surface Contour
x
y
w
b


Data Space Iteration: 62
Loss Surface Contour
x
y
w
b

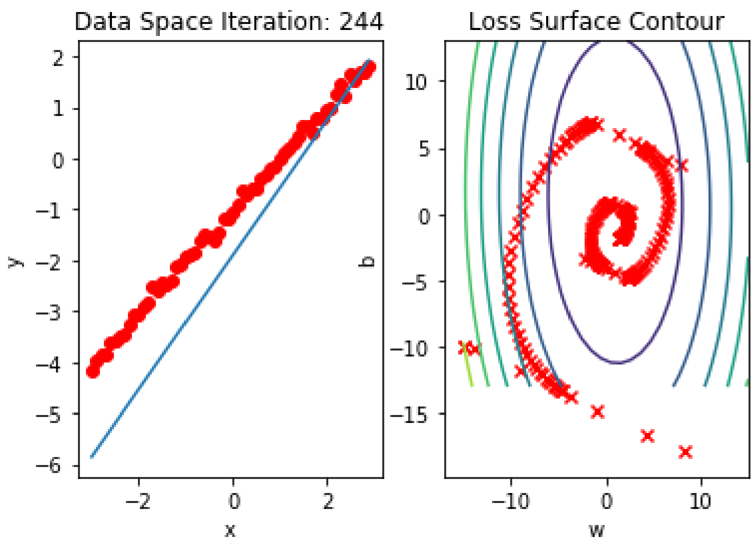

Data Space Iteration: 122
Loss Surface Contour
x
y
w
b


Data Space Iteration: 123
Loss Surface Contour
x
y
w
b

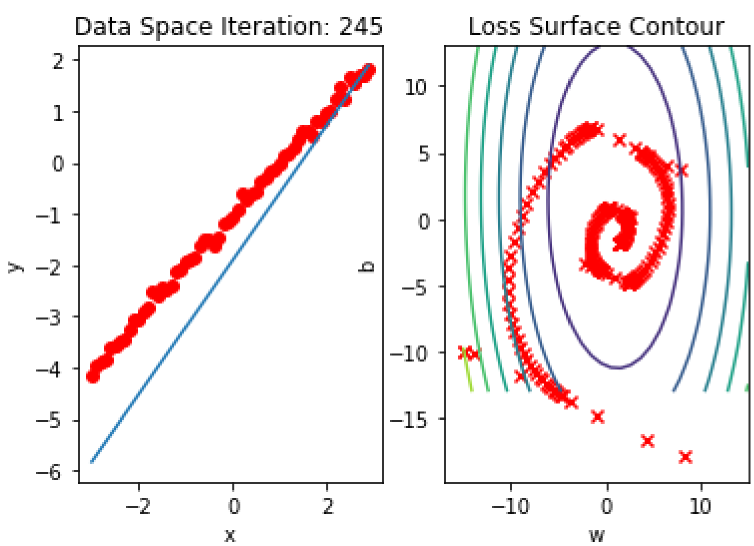

Data Space Iteration: 183
Loss Surface Contour
x
y
w
b



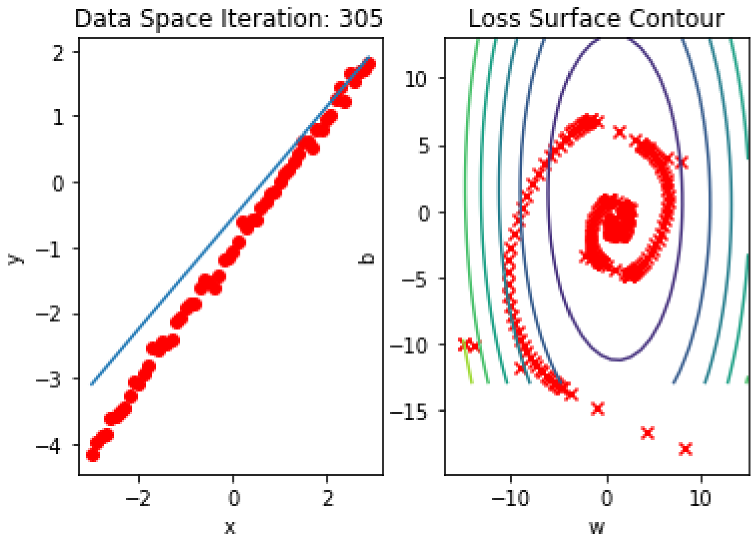
Data Space Iteration: 184
Loss Surface Contour
x
y
w
b

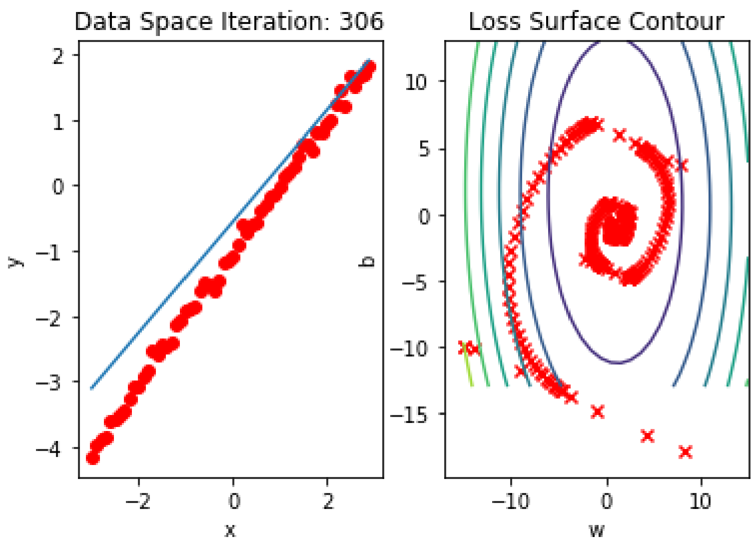


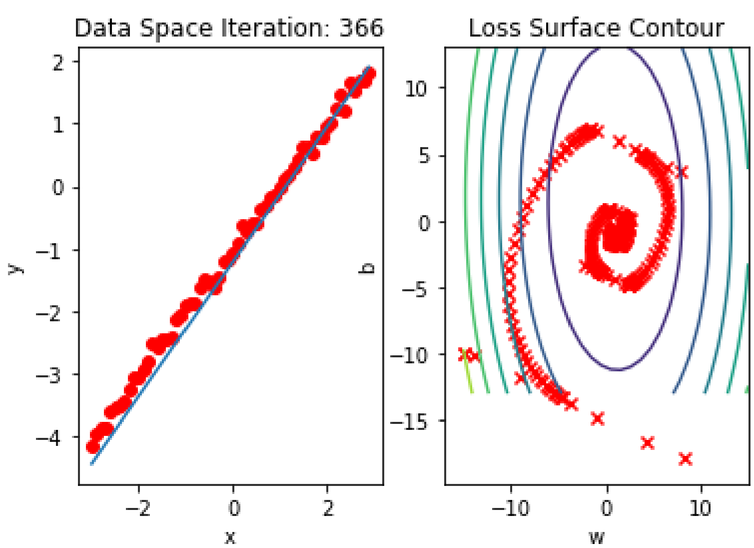
Data Space Iteration: 244
Loss Surface Contour
x
y
w
b

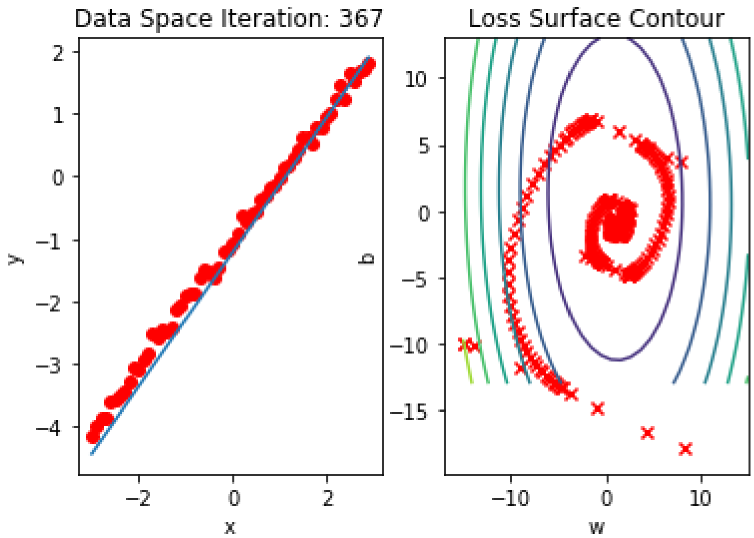


Data Space Iteration: 245
Loss Surface Contour
x
y
w
b

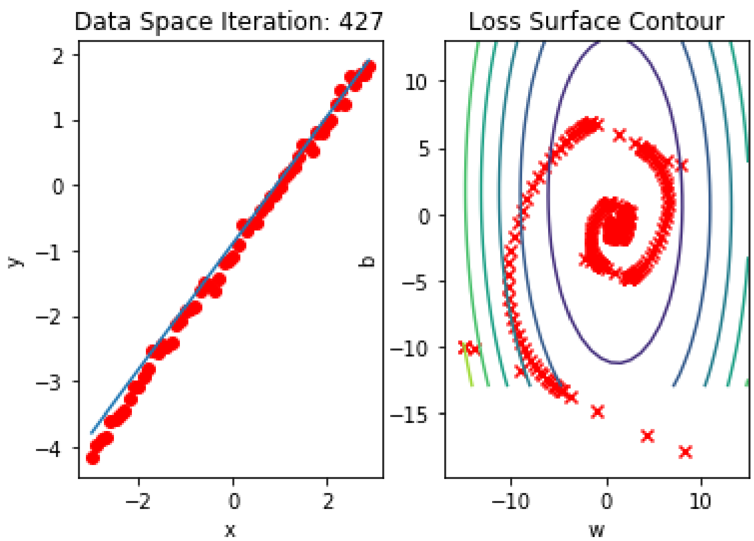

Data Space Iteration: 305
Loss Surface Contour
y
x
b
w


Data Space Iteration: 306
Loss Surface Contour
y
x
b
w

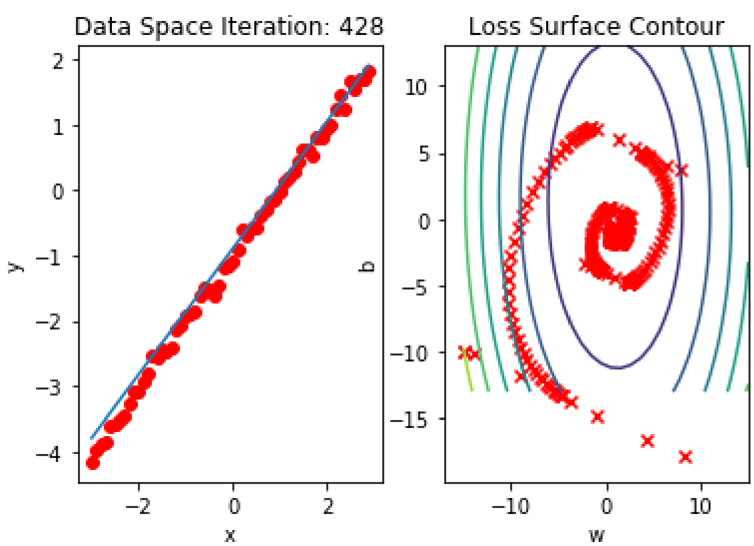

Data Space Iteration: 366
Loss Surface Contour
y
x
b
w



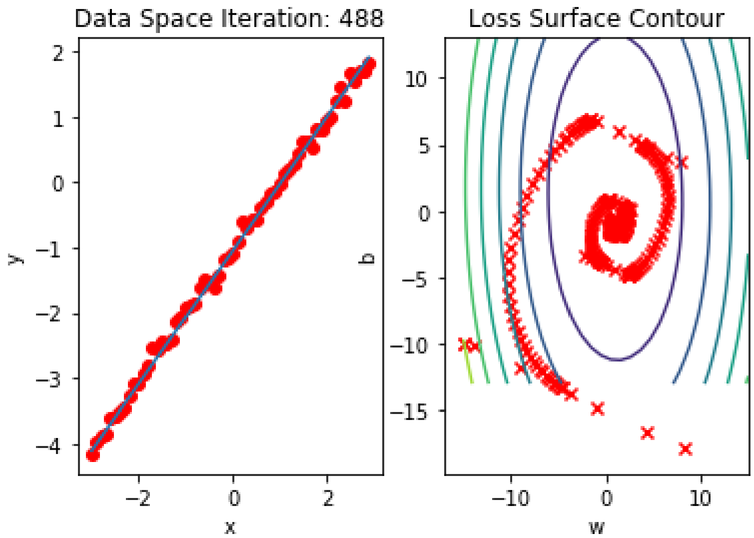
Data Space Iteration: 367
Loss Surface Contour
x
y
w
b

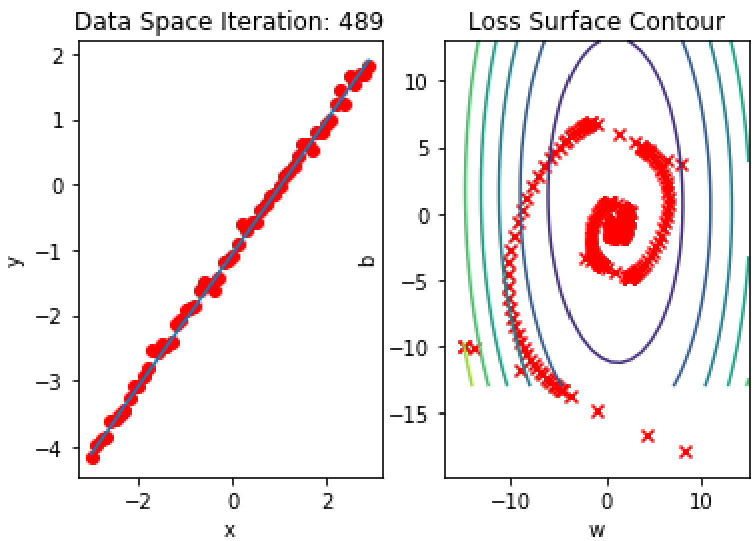


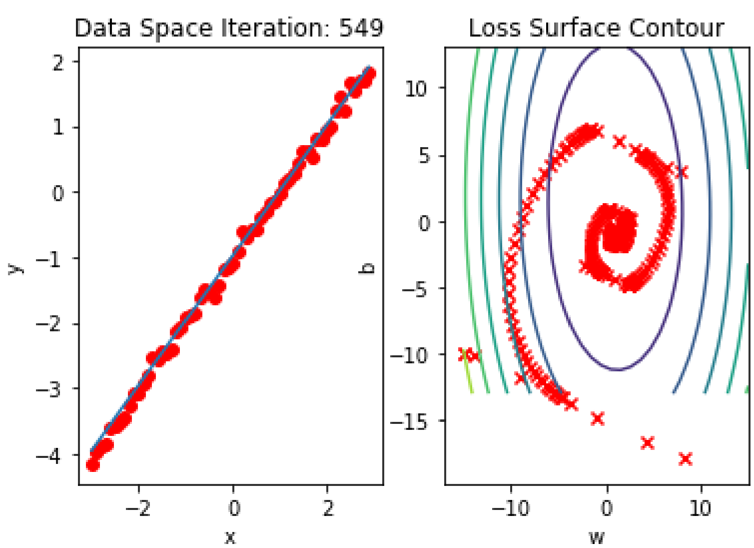
Data Space Iteration: 427
Loss Surface Contour
x
y
w
b

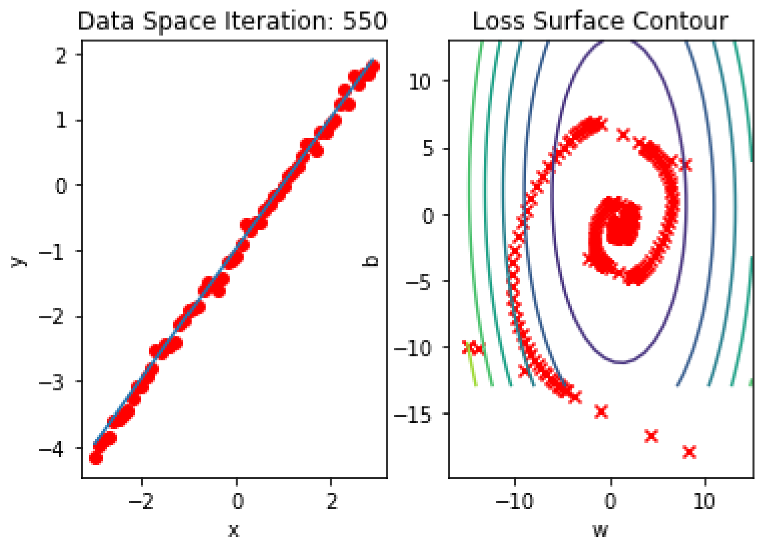


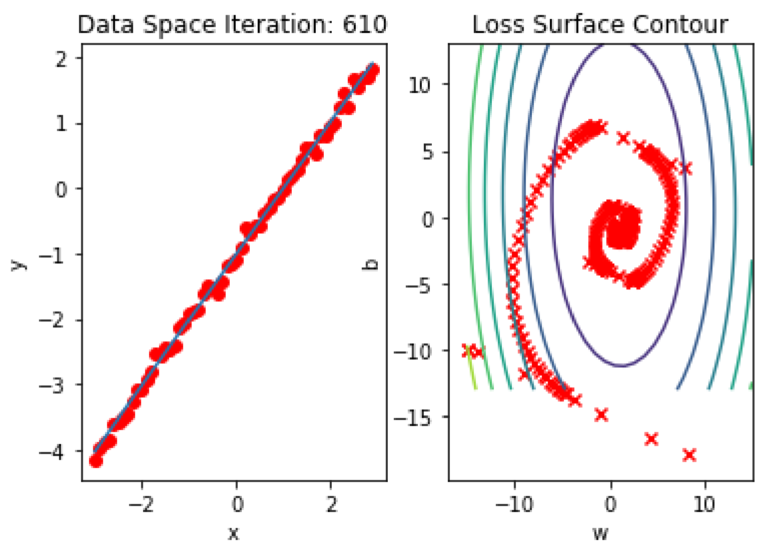
Data Space Iteration: 428
Loss Surface Contour
x
y
w
b


Data Space Iteration: 488
Loss Surface Contour
x
y
w
b


Data Space Iteration: 489
Loss Surface Contour
x
y
w
b


Data Space Iteration: 549
Loss Surface Contour
x
y
w
b





Mini Batch Gradient Descent: Batch Size Equals 5

Create a `plot_error_surfaces` object to visualize the data space and the parameter space during training:

In [17]:

```
# Create a plot_error_surfaces object.

get_surface = plot_error_surfaces(15, 13, X, Y, 30, go = False)
```

Create `Data` object and create a `Dataloader` object where the batch size equals 5:

In [18]:

```
# Create DataLoader object and Data object

dataset = Data()
trainloader = DataLoader(dataset = dataset, batch_size = 5)
```

Define `train_model_Mini5` function to train the model.

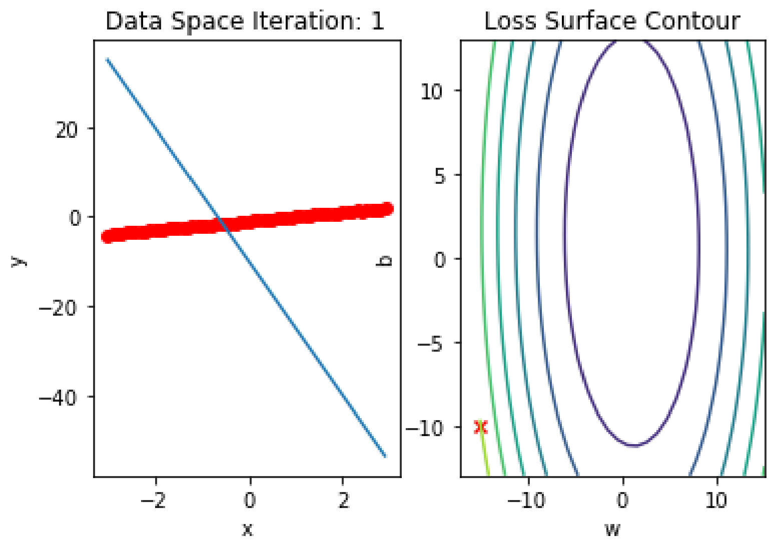
In [19]:

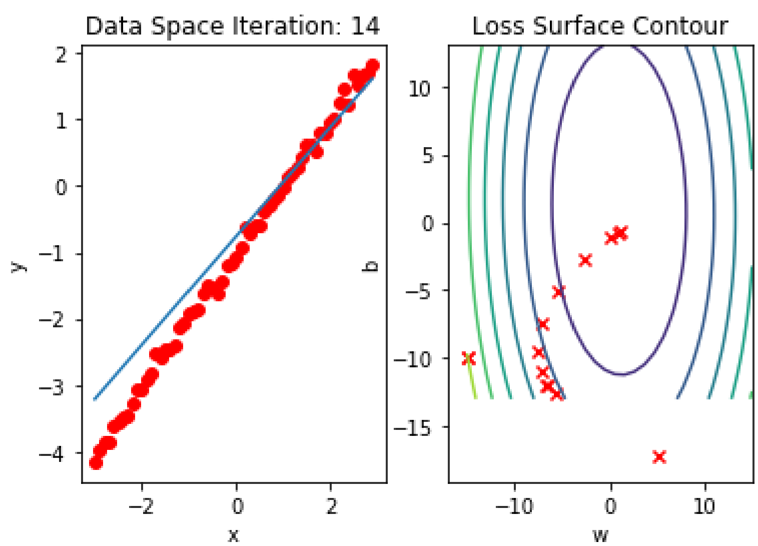
```
# Define train_model_Mini5 function

w = torch.tensor(-15.0, requires_grad = True)
b = torch.tensor(-10.0, requires_grad = True)
LOSS_MINI5 = []
lr = 0.1

def train_model_Mini5(epochs):
    for epoch in range(epochs):
        Yhat = forward(X)
        get_surface.set_para_loss(w.data.tolist(), b.data.tolist(), criterion(Yhat, 
Y).tolist())
        get_surface.plot_ps()
        LOSS_MINI5.append(criterion(forward(X), Y).tolist())
        for x, y in trainloader:
            yhat = forward(x)
            loss = criterion(yhat, y)
            get_surface.set_para_loss(w.data.tolist(), b.data.tolist(), loss.tolist
())
            loss.backward()
            w.data = w.data - lr * w.grad.data
            b.data = b.data - lr * b.grad.data
            w.grad.data.zero_()
            b.grad.data.zero_()
```

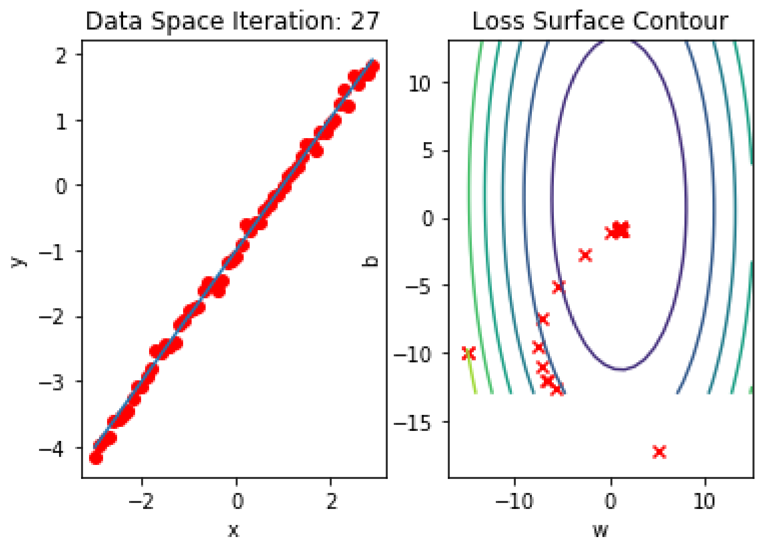
Run 10 epochs of mini-batch gradient descent: **bug** data space is 1 iteration ahead of parameter space.

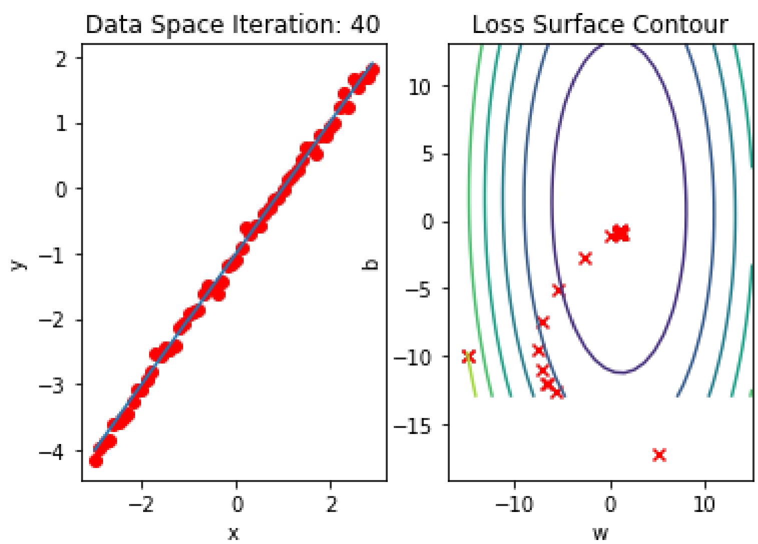
In [20]:

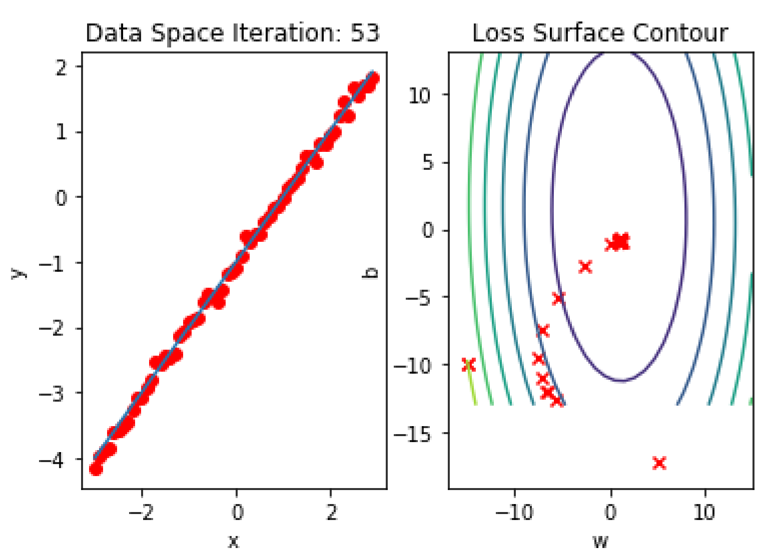
```
# Run train_model_Mini5 with 10 iterations.

train_model_Mini5(10)
```

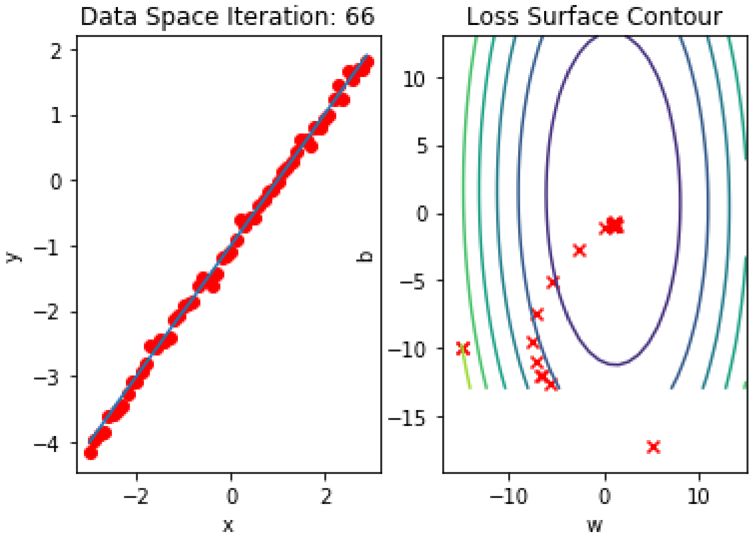

Data Space Iteration: 1
Loss Surface Contour
x
y
w
b

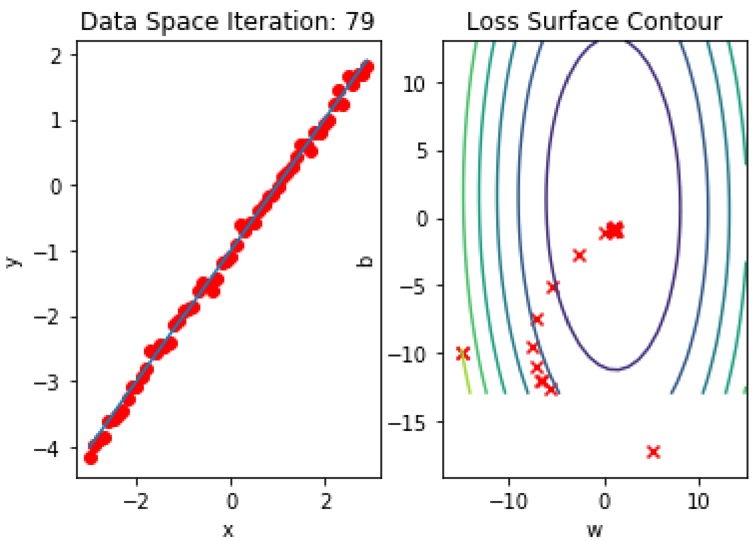

Data Space Iteration: 14
Loss Surface Contour
x
y
w
b

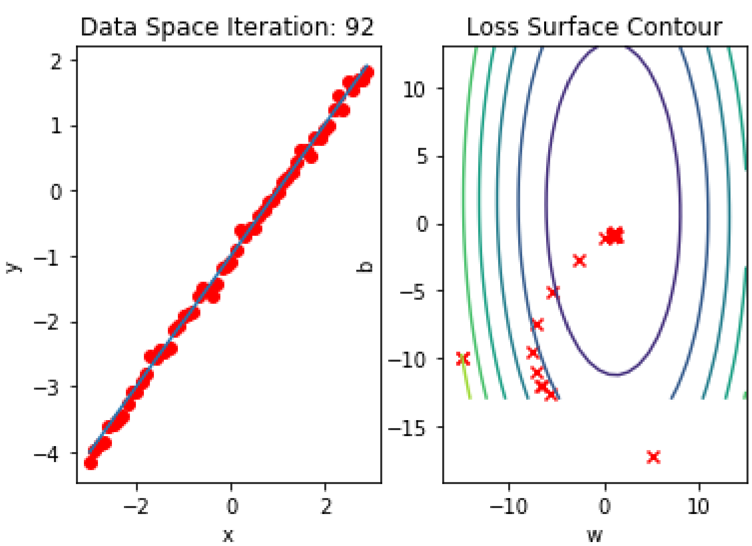

Data Space Iteration: 27
Loss Surface Contour
x
y
w
b

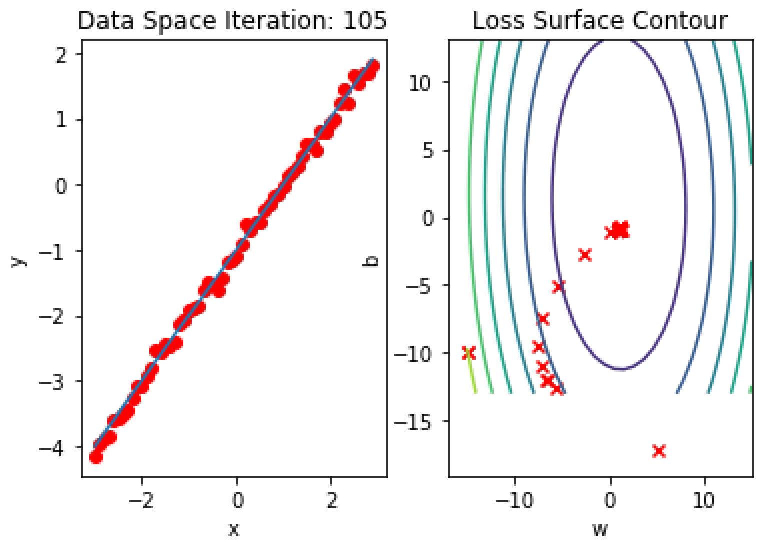

Data Space Iteration: 40
Loss Surface Contour
x
y
w
b

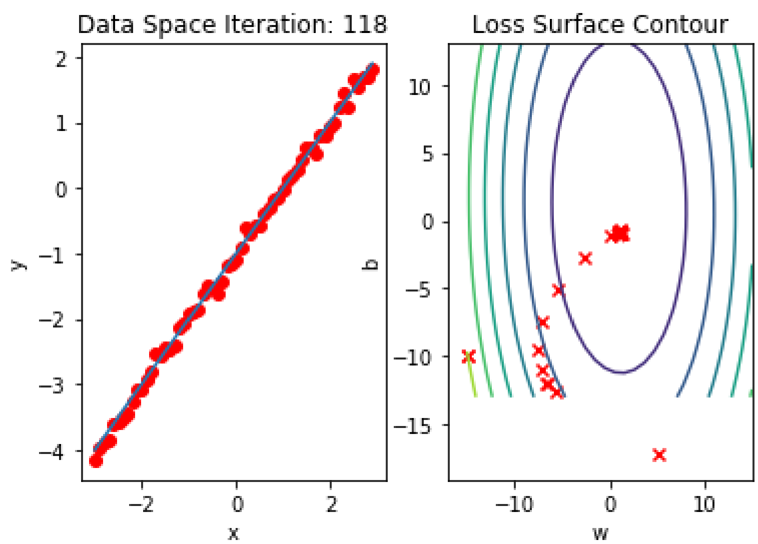

Data Space Iteration: 53
Loss Surface Contour
x
y
w
b


Data Space Iteration: 66
Loss Surface Contour
x
y
w
b


Data Space Iteration: 79
Loss Surface Contour
x
y
w
b


Data Space Iteration: 92
Loss Surface Contour
x
y
w
b





Mini Batch Gradient Descent: Batch Size Equals 10

Create a `plot_error_surfaces` object to visualize the data space and the parameter space during training:

In [21]:

```
# Create a plot_error_surfaces object.

get_surface = plot_error_surfaces(15, 13, X, Y, 30, go = False)
```

Create `Data` object and create a `Dataloader` object batch size equals 10

In [22]:

```
# Create DataLoader object

dataset = Data()
trainloader = DataLoader(dataset = dataset, batch_size = 10)
```

Define `train_model_Mini10` function for training the model.

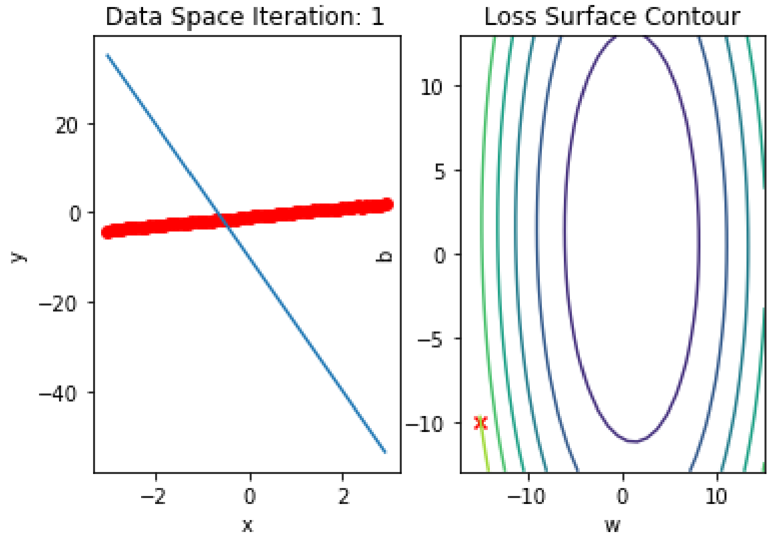
In [23]:

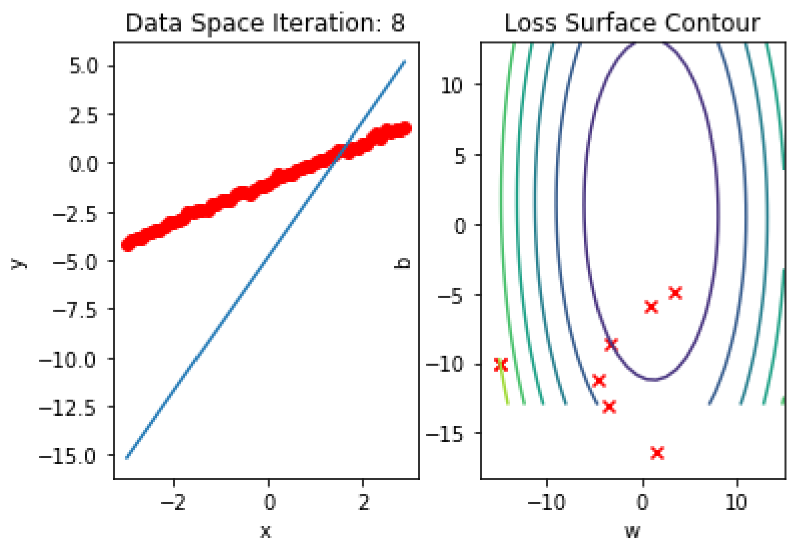
```
# Define train_model_Mini5 function

w = torch.tensor(-15.0, requires_grad = True)
b = torch.tensor(-10.0, requires_grad = True)
LOSS_MINI10 = []
lr = 0.1

def train_model_Mini10(epochs):
    for epoch in range(epochs):
        Yhat = forward(X)
        get_surface.set_para_loss(w.data.tolist(), b.data.tolist(), criterion(Yhat,
Y).tolist())
        get_surface.plot_ps()
        LOSS_MINI10.append(criterion(forward(X),Y).tolist())
        for x, y in trainloader:
            yhat = forward(x)
            loss = criterion(yhat, y)
            get_surface.set_para_loss(w.data.tolist(), b.data.tolist(), loss.tolist
())
            loss.backward()
            w.data = w.data - lr * w.grad.data
            b.data = b.data - lr * b.grad.data
            w.grad.data.zero_()
            b.grad.data.zero_()
```

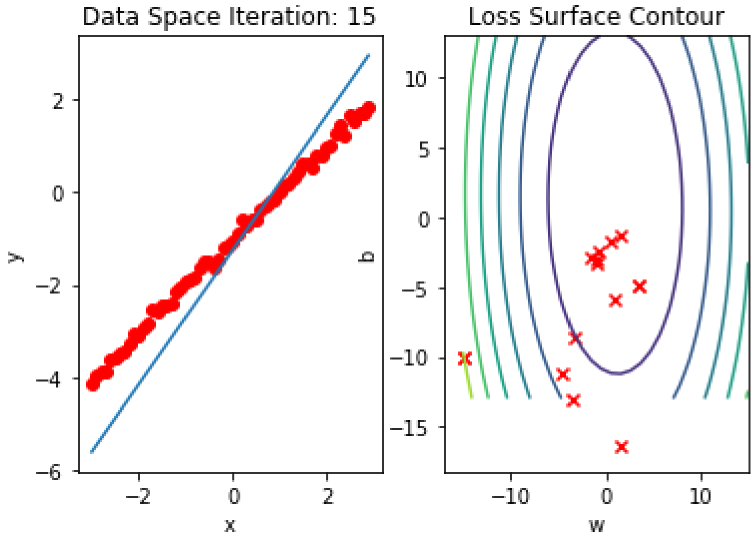
Run 10 epochs of mini-batch gradient descent: **bug** data space is 1 iteration ahead of parameter space.

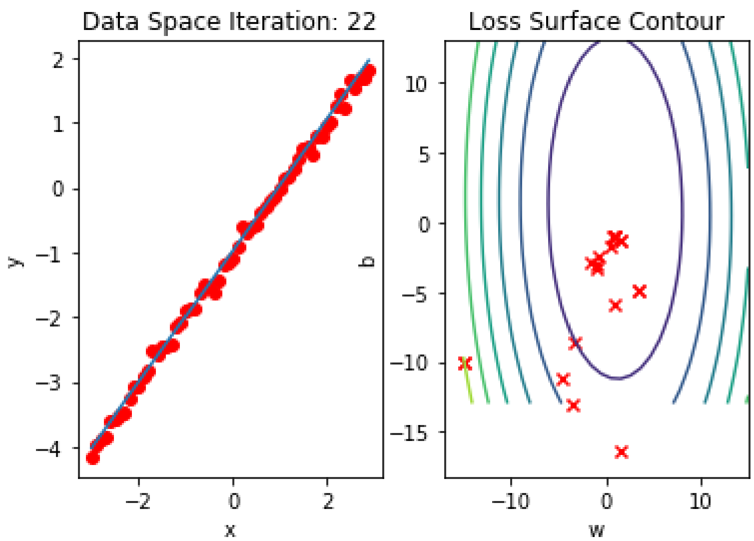
In [24]:

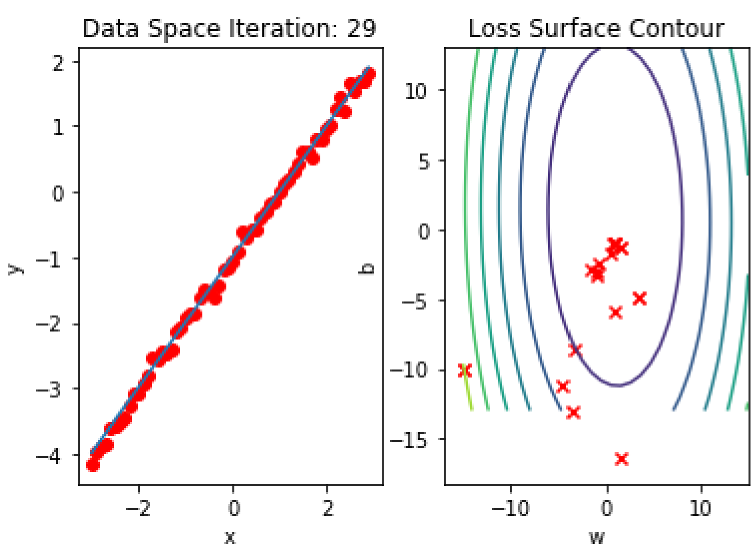
```
# Run train_model_Mini5 with 10 iterations.

train_model_Mini10(10)
```

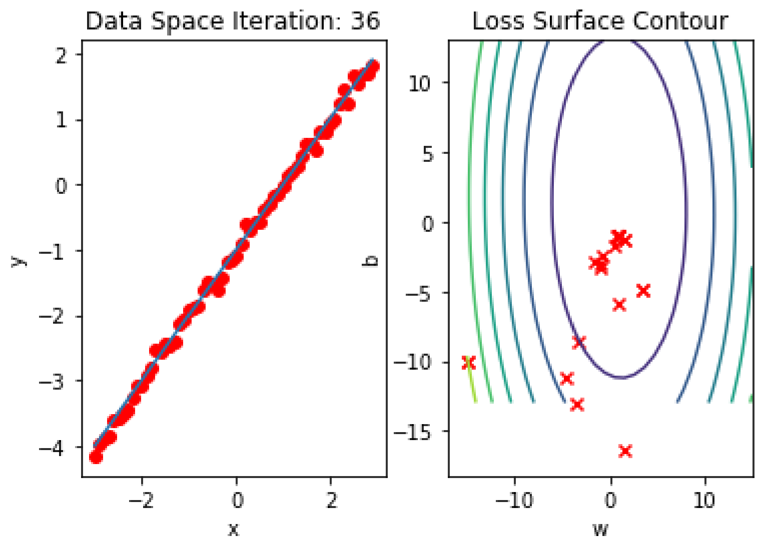

Data Space Iteration: 1
Loss Surface Contour
20
0
−20
−40
−2
0
2
x
y
10
5
0
−5
−10
−10
0
10
w
b

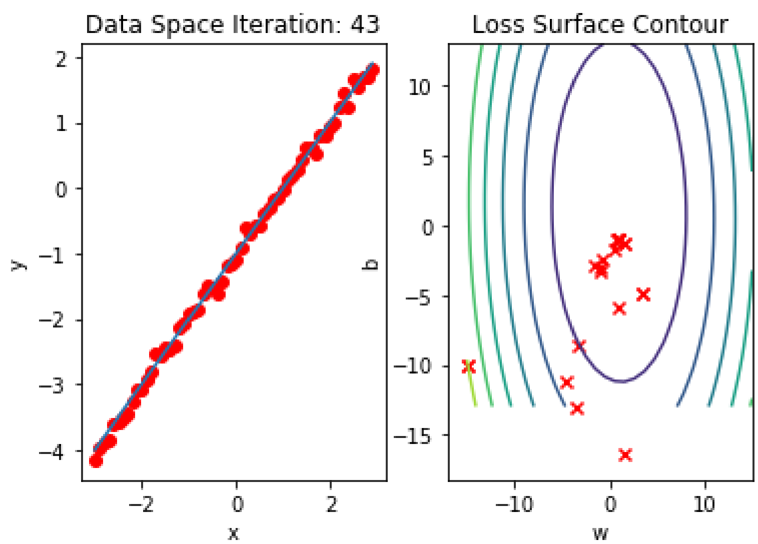

Data Space Iteration: 8
Loss Surface Contour
5.0
2.5
0.0
−2.5
−5.0
−7.5
−10.0
−12.5
−15.0
−2
0
2
x
y
10
5
0
−5
−10
−15
−10
0
10
w
b

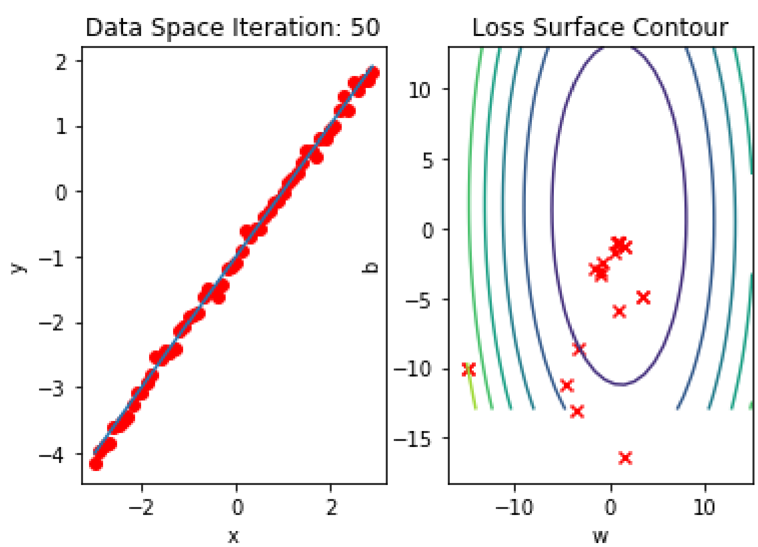

Data Space Iteration: 15
Loss Surface Contour
y
x
b
w
2
0
−2
−4
−6
−2
0
2
10
5
0
−5
−10
−15
−10
0
10

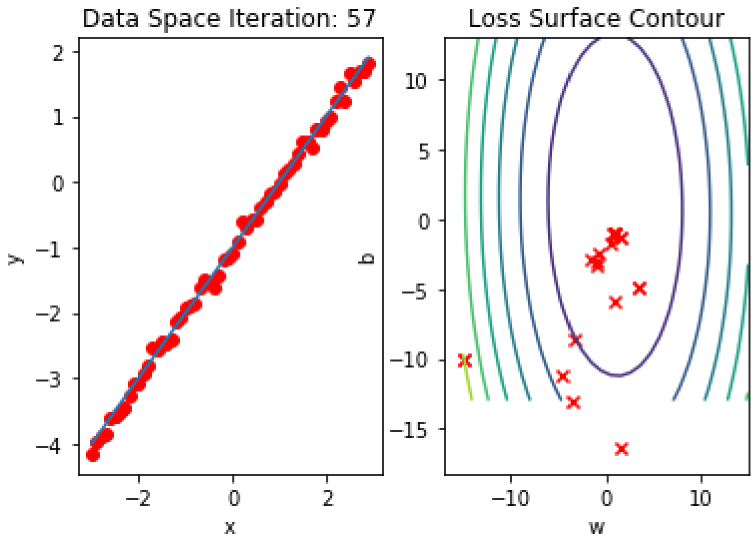

Data Space Iteration: 22
Loss Surface Contour
y
x
b
w
2
1
0
−1
−2
−3
−4
−2
0
2
10
5
0
−5
−10
−15
−10
0
10

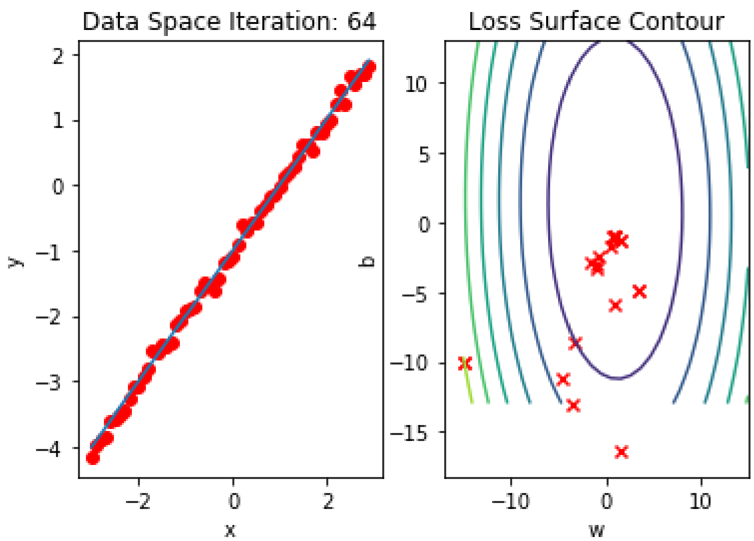

Data Space Iteration: 29
Loss Surface Contour
y
x
b
w
2
1
0
−1
−2
−3
−4
−2
0
2
10
5
0
−5
−10
−15
−10
0
10


Data Space Iteration: 36
Loss Surface Contour
2
1
0
−1
−2
−3
−4
y
−2
0
2
x
10
5
0
−5
−10
−15
b
−10
0
10
w


Data Space Iteration: 43
Loss Surface Contour
2
1
0
−1
−2
−3
−4
y
−2
0
2
x
10
5
0
−5
−10
−15
b
−10
0
10
w


Data Space Iteration: 50
Loss Surface Contour
2
1
0
−1
−2
−3
−4
y
−2
0
2
x
10
5
0
−5
−10
−15
b
−10
0
10
w





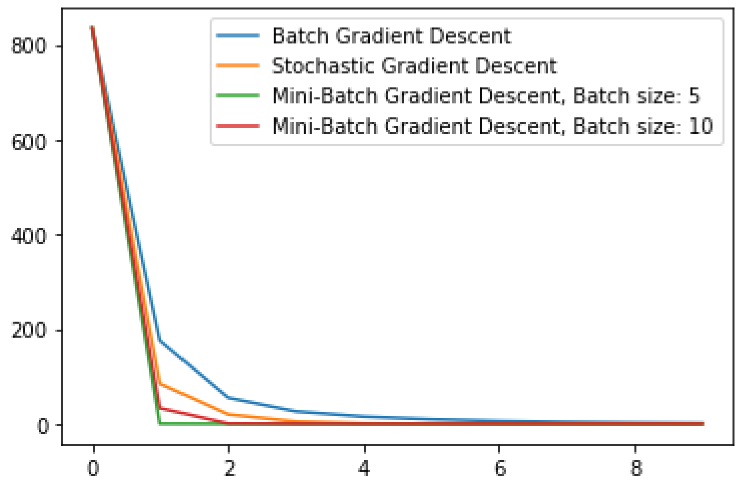
Plot the loss for each epoch:

In [25]:

```
# Plot out the LOSS for each method

plt.plot(LOSS_BGD,label = "Batch Gradient Descent")
plt.plot(LOSS_SGD,label = "Stochastic Gradient Descent")
plt.plot(LOSS_MINI5,label = "Mini-Batch Gradient Descent, Batch size: 5")
plt.plot(LOSS_MINI10,label = "Mini-Batch Gradient Descent, Batch size: 10")
plt.legend()
```

Out[25]:

```
<matplotlib.legend.Legend at 0x7f23703b8b38>
```

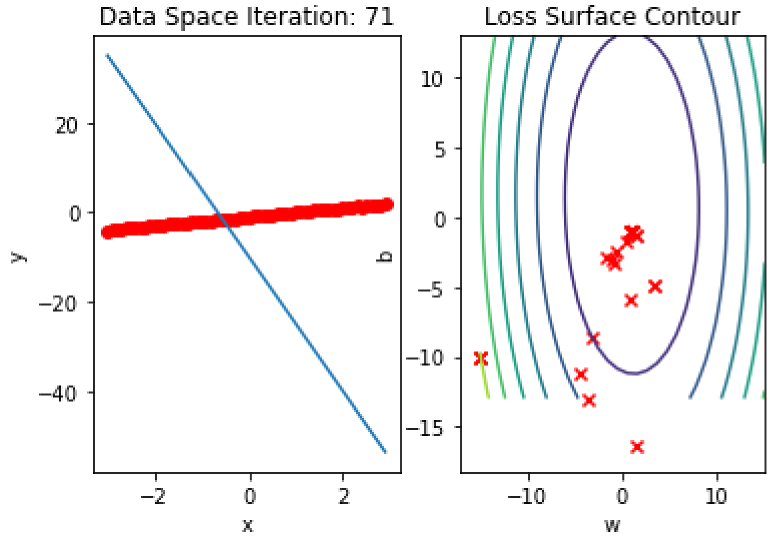


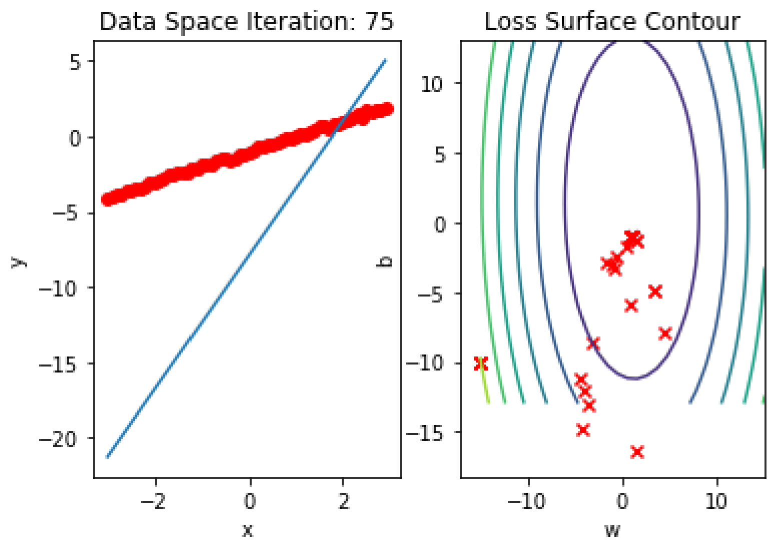
Practice

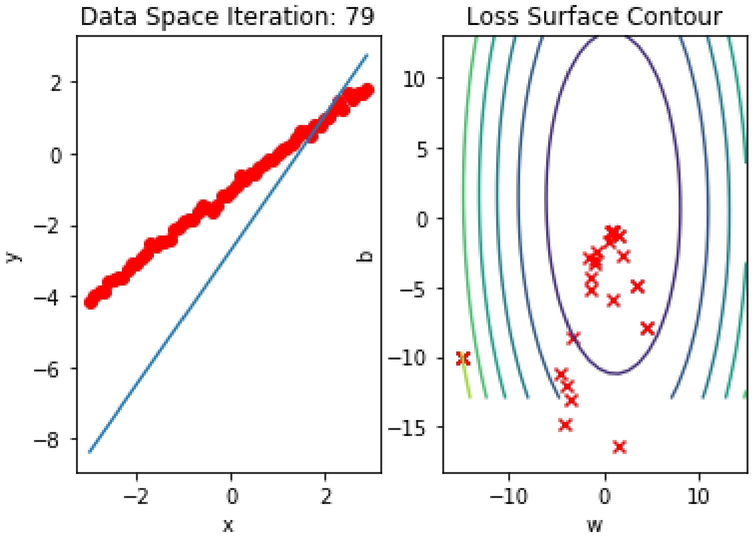
Perform mini batch gradient descent with a batch size of 20. Store the total loss for each epoch in the list LOSS20.

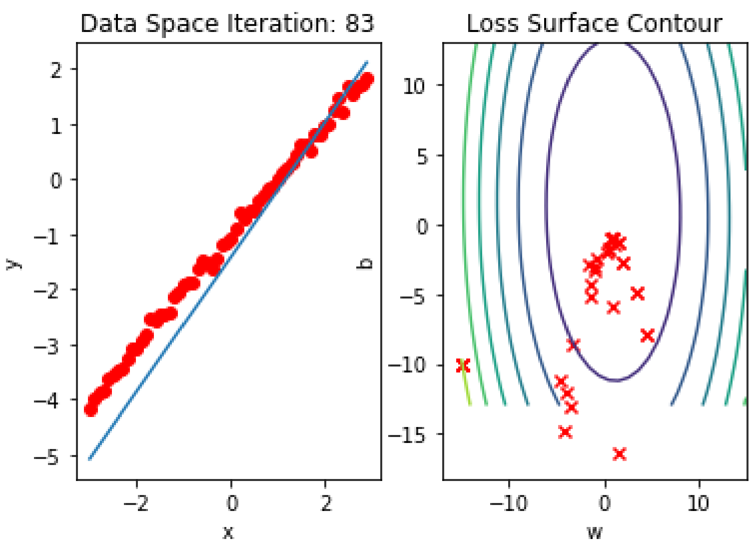
In [26]:

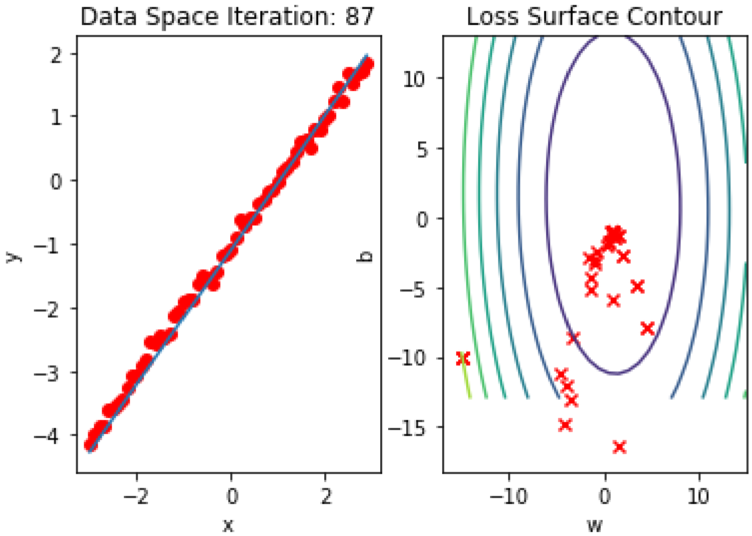
```
# Practice: Perform mini batch gradient descent with a batch size of 20.

dataset = Data()
trainloader = DataLoader(dataset = dataset, batch_size = 20)
w = torch.tensor(-15.0, requires_grad = True)
b = torch.tensor(-10.0, requires_grad = True)

LOSS_MINI20 = []
lr = 0.1

def my_train_model(epochs):
    for epoch in range(epochs):
        Yhat = forward(X)
        get_surface.set_para_loss(w.data.tolist(), b.data.tolist(), criterion(Yhat,
Y).tolist())
        get_surface.plot_ps()
        LOSS_MINI20.append(criterion(forward(X), Y).tolist())
        for x, y in trainloader:
            yhat = forward(x)
            loss =criterion(yhat, y)
            get_surface.set_para_loss(w.data.tolist(), b.data.tolist(), loss.tolist
())
            loss.backward()
            w.data = w.data - lr * w.grad.data
            b.data = b.data - lr * b.grad.data
            w.grad.data.zero_()
            b.grad.data.zero_()
my_train_model(10)
```

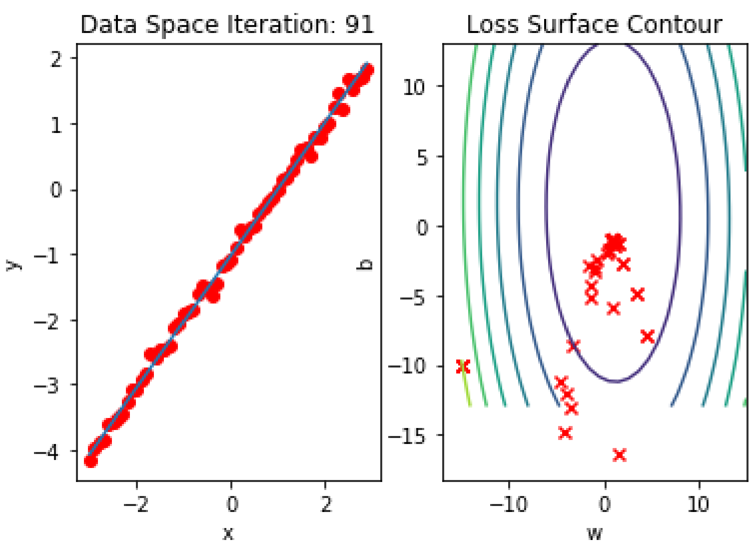

Data Space Iteration: 71
Loss Surface Contour
y
x
b
w

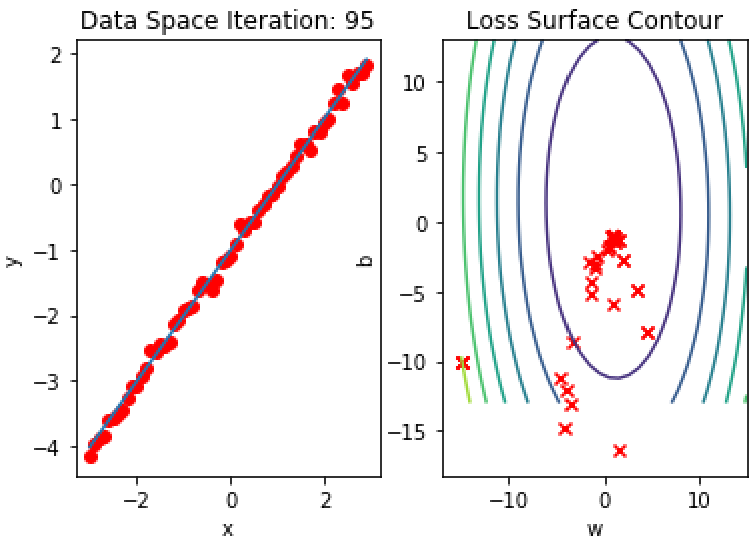

Data Space Iteration: 75
Loss Surface Contour
y
x
b
w

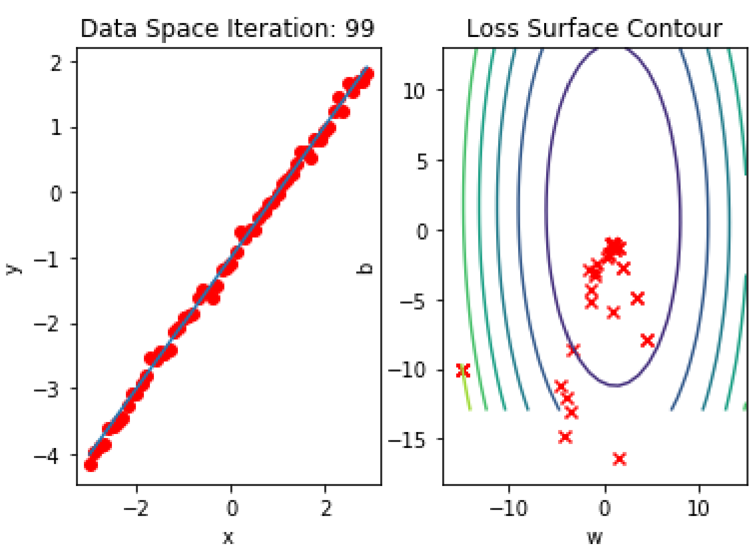

Data Space Iteration: 79
Loss Surface Contour
y
x
b
w

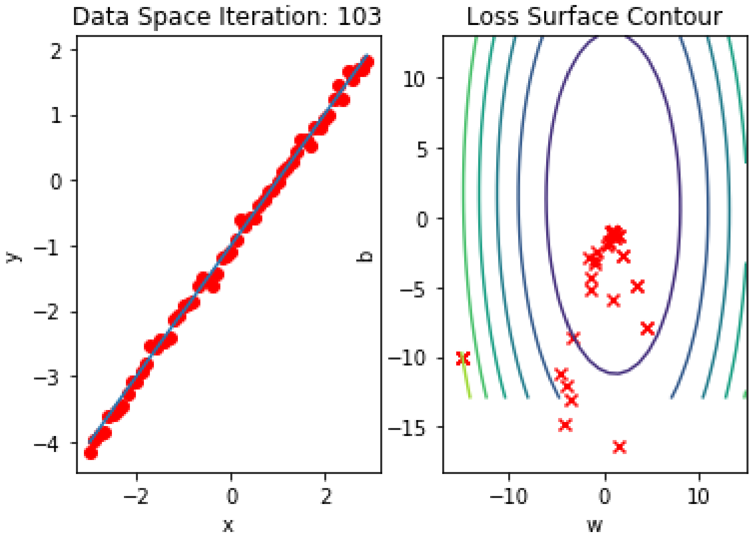

Data Space Iteration: 83
Loss Surface Contour
y
x
b
w

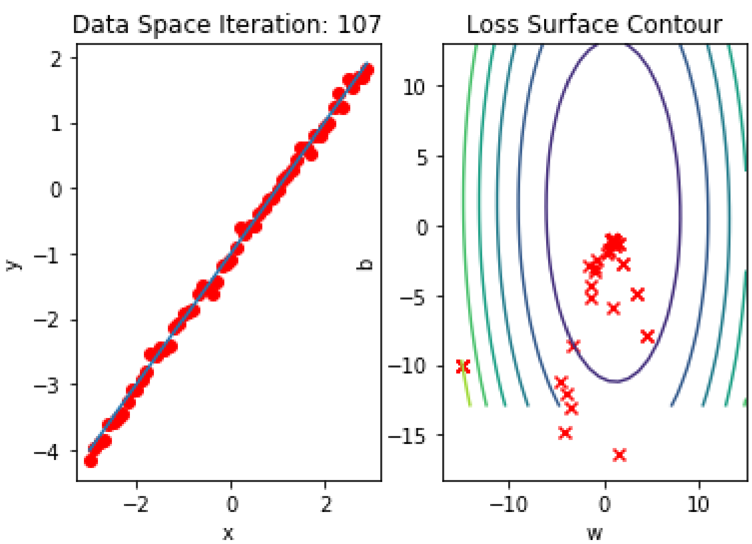

Data Space Iteration: 87
Loss Surface Contour
y
x
b
w


Data Space Iteration: 91
Loss Surface Contour
y
x
b
w


Data Space Iteration: 95
Loss Surface Contour
x
y
w
b


Data Space Iteration: 99
Loss Surface Contour
x
y
w
b





Double-click **here** for the solution.

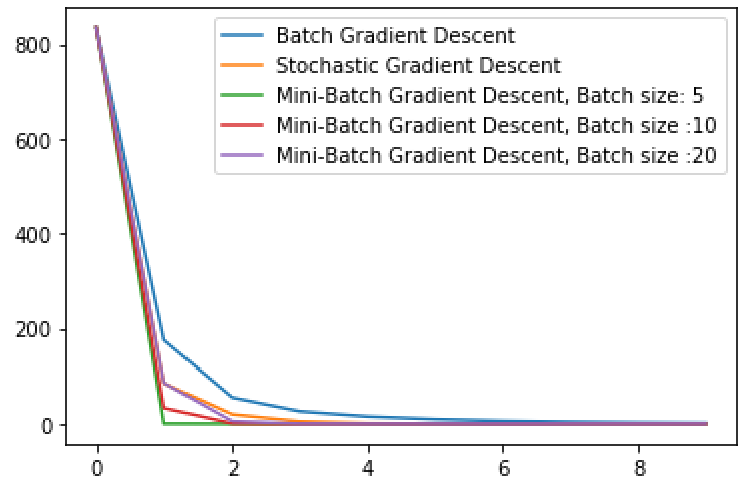
Plot a graph that shows the LOSS results for all the methods.

In [27]:

```python
# Practice: Plot a graph to show all the LOSS functions
plt.plot(LOSS_BGD, label = 'Batch Gradient Descent')
plt.plot(LOSS_SGD, label = 'Stochastic Gradient Descent')
plt.plot(LOSS_MINI5, label = 'Mini-Batch Gradient Descent, Batch size: 5')
plt.plot(LOSS_MINI10, label = 'Mini-Batch Gradient Descent, Batch size :10')
plt.plot(LOSS_MINI20, label = 'Mini-Batch Gradient Descent, Batch size :20')
plt.legend()
```

Out[27]:

```
<matplotlib.legend.Legend at 0x7f237007e4a8>
```



Double-click **here** for the solution.

About the Authors:

Joseph Santarcangelo (https://www.linkedin.com/in/joseph-s-50398b136/) has a PhD in Electrical Engineering, his research focused on using machine learning, signal processing, and computer vision to determine how videos impact human cognition. Joseph has been working for IBM since he completed his PhD.

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