In [7]:
```
import matplotlib.pyplot as plt
import numpy as np
from os import listdir
from sklearn import linear_model
from sklearn.linear_model import lasso_path
from warnings import filterwarnings
filterwarnings('ignore')

np.random.seed(2019)

def extract_temp(file_name,col_ind):
    data_aux = np.loadtxt(file_name, usecols=range(10))
    data = data_aux[:,col_ind]
    err_count = 0
    ind_errs = []
    for ind in range(data.shape[0]):
        if data[ind] > 100 or data[ind] < -100:
            err_count = err_count + 1
            ind_errs.append(ind)
            data[ind] = data[ind-1]
    print("File name: " + file_name)
    print("Errors: " + str(err_count) + " Indices: " + str(ind_errs))
    return data

def create_data_matrix(str_path):
    file_name_list = listdir(str_path)
    file_name_list.sort()
    col_ind = 8 # 8 = last 5 minutes, 9 = average over the whole hour
    data_matrix = []
    ind = 0
    for file_name in file_name_list:
        if file_name[0] == '.':
            continue
        else:
            print("Station " + str(ind))
            ind = ind + 1
            data_aux = extract_temp(str_path + file_name,col_ind)
            if len(data_matrix) == 0:
                data_matrix = data_aux
            else:
                data_matrix = np.vstack((data_matrix,data_aux))
    return data_matrix.T

def FSR(X,y,num_features=20):
    '''
    X: feature matrix
    y: response
    return
        coeff: coefficient betta
    '''
    S=[]
    r=y
    beta = np.zeros(X.shape[1])
    while len(S)<num_features:
        i = np.argmax(np.abs(X.T@r))
        S.append(i)
```

```
        beta[S]=np.linalg.pinv(X[:,S].T@X[:,S])@X[:,S].T@y
        r=y -X@beta

    coeff= beta

    return coeff
```

In [8]:
```
str_path = "./weather/"

load_files = False
if load_files:
    str_path_2015 = str_path + "hourly/2015/"
    data_matrix = create_data_matrix(str_path_2015)
    str_path_2016 = str_path + "hourly/2016/"
    data_matrix_2016 = create_data_matrix(str_path_2016)
else:
    data_matrix = np.load(str_path +"hourly_temperature_2015.npy")
    data_matrix_2016 = np.load(str_path +"hourly_temperature_2016.npy")

file_name_list = listdir(str_path + "hourly/2015/")
file_name_list.sort()


ind_response = 78 # 53 = Manhattan, 18 = Troy has 2 correlated features
# 23 = Williams dense linear model 30 = Death Valley 16 = AL_Talladega_10_N
# 78 = ND Jamestown also good for enet
print("Response is " + str(file_name_list[ind_response]))
y_raw = data_matrix[:,ind_response]
y_2016 = data_matrix_2016[:,ind_response]
ind_X = np.hstack((np.arange(0,ind_response),np.arange(ind_response+1,data_
X_raw = data_matrix[:,ind_X]
X_2016 = data_matrix_2016[:,ind_X]
n_features = X_raw.shape[1]

n_train_values = 40
n_test = int(1e3)
n_val = int(1e3)
n_train_max = data_matrix.shape[0] - n_test # 5e2
n_train_min = 133
n_train_list = np.around(np.logspace(np.log10(n_train_min),np.log10(n_train
train_error_lasso_vec = []
val_error_lasso_vec = []
test_error_lasso_vec = []
test_2016_lasso_vec = []
train_error_ridge_vec = []
val_error_ridge_vec = []
test_error_ridge_vec = []
test_2016_ridge_vec = []

train_error_fsr_vec = []
val_error_fsr_vec = []
test_error_fsr_vec = []
test_2016_fsr_vec = []

coeffs_lasso_matrix = np.zeros((n_features,len(n_train_list)))
coeffs_ridge_matrix = np.zeros((n_features,len(n_train_list)))
coeffs_fsr_matrix = np.zeros((n_features,len(n_train_list)))
lambda_lasso_vec = []
lambda_ridge_vec = []
n_features_fsr_vec = []

n_lambda = 50
lambdas_ridge_aux = np.logspace(-5, 2, n_lambda)
```

```
lambdas_lasso = np.logspace(-5, 2, n_lambda)
eps = 1e-5  # the smaller it is the longer is the path
fixed_n = n_train_list[9]

i_m = 0
for n_train in n_train_list:
    lambdas_ridge = lambdas_ridge_aux * n_train
    aux_ind = np.random.permutation(range(data_matrix.shape[0]))
    ind_test = aux_ind[:n_test]
    ind_val = aux_ind[n_test:(n_test+n_val)]
    X_test = X_raw[ind_test,:]
    y_test = y_raw[ind_test]
    X_val = X_raw[ind_val,:]
    y_val = y_raw[ind_val]
    ind_train = aux_ind[(n_test+n_val):int(n_test+n_val+n_train)]
    X_train = X_raw[ind_train,:]
    y_train = y_raw[ind_train]

    center_vec = X_train.mean(axis=0)
    X_train_centered = X_train - center_vec
    col_norms = np.linalg.norm(X_train_centered, axis=0) / np.sqrt(n_train)
    X_train_norm = np.true_divide(X_train_centered, col_norms)
    X_test_centered = X_test - center_vec
    X_test_norm = np.true_divide(X_test_centered, col_norms)
    X_val_centered = X_val - center_vec
    X_val_norm = np.true_divide(X_val_centered, col_norms)
    X_2016_centered = X_2016 - center_vec
    X_2016_norm = np.true_divide(X_2016_centered, col_norms)
    y_train_center = y_train.mean()
    y_train_centered = y_train - y_train_center
    norm_y_train = np.linalg.norm(y_train_centered) / np.sqrt(n_train)
    y_train_norm = y_train_centered / norm_y_train

    print("Computing regularization path using the lasso...")
    lambdas_lasso, coeffs_lasso, _ = lasso_path(X_train_norm, y_train_norm,
                                        alphas = lambdas_lasso, fit_inter

    min_error_val = 1e4
    i_lambda = 0
    val_error_lasso_lambdas = np.zeros(n_lambda)
    train_error_lasso_lambdas = np.zeros(n_lambda)
    for i, coeffs_est in enumerate(coeffs_lasso.T):
        y_val_lasso = norm_y_train * np.dot(X_val_norm, coeffs_est) + y_tra
        error_val = np.linalg.norm(y_val - y_val_lasso) / np.sqrt(len(y_val
        # error_val_vec.append(error_val)
        if error_val < min_error_val:
            min_error_val = error_val
            lambda_best_lasso = lambdas_lasso[i]
            coeffs_lasso_best = coeffs_est
        y_train_lasso = norm_y_train * np.dot(X_train_norm, coeffs_est) + y
        train_error_lasso_lambdas[i] =  np.linalg.norm(y_train - y_train_la
        val_error_lasso_lambdas[i] = error_val
    lambda_lasso_vec.append(lambda_best_lasso)
    y_train_lasso = norm_y_train * np.dot(X_train_norm, coeffs_lasso_best)
    y_test_lasso = norm_y_train * np.dot(X_test_norm, coeffs_lasso_best) +
    y_2016_lasso = norm_y_train * np.dot(X_2016_norm, coeffs_lasso_best) +
    train_error_lasso = np.linalg.norm(y_train - y_train_lasso) / np.sqrt(l
```

```
test_error_lasso = np.linalg.norm(y_test - y_test_lasso) / np.sqrt(len(
test_2016_lasso = np.linalg.norm(y_2016 - y_2016_lasso) / np.sqrt(len(y
train_error_lasso_vec.append(train_error_lasso)
val_error_lasso_vec.append(min_error_val)
test_error_lasso_vec.append(test_error_lasso)
test_2016_lasso_vec.append(test_2016_lasso)
coeffs_lasso_matrix[:,i_m] = coeffs_lasso_best


if n_train == fixed_n:
    coeffs_lasso_fixed = np.copy(coeffs_lasso)
    plt.figure()
    plt.plot(lambdas_lasso,coeffs_lasso.T)
    plt.plot(lambdas_lasso,val_error_lasso_lambdas/10.,marker='o')
    plt.plot(lambdas_lasso,train_error_lasso_lambdas/10.,marker='x')
    plt.xscale('log')
    plt.title('Lasso: n = ' + str(n_train))

    plt.figure(figsize=(8,6))
    plt.plot(lambdas_lasso,train_error_lasso_lambdas,marker='o',linesty
    plt.plot(lambdas_lasso,val_error_lasso_lambdas,marker='o',linestyle
    plt.xlabel(r"Regularization parameter ($\lambda$)",fontsize=14)
    plt.ylabel('Average error (deg Celsius)',fontsize=14)
    plt.gcf().subplots_adjust(bottom=0.15)
    plt.xscale('log')
    plt.legend(loc = 'lower right',fontsize=14)


# ridge regression
clf = linear_model.Ridge(fit_intercept=False, normalize=False,)
min_error_val = 1e3
lambda_best = 0
coeffs_ridge = np.zeros((n_features,n_lambda))
val_error_ridge_lambdas = np.zeros(n_lambda)
for ind_a,a in enumerate(lambdas_ridge):
    # print "lambda: " + str(a)
    clf.set_params(alpha=a)
    clf.fit(X_train_norm, y_train_norm)
    coeffs_ridge[:,ind_a] = clf.coef_
    y_val_ridge = norm_y_train * np.dot(X_val_norm, clf.coef_) + y_trai
    error_val = np.linalg.norm(y_val - y_val_ridge) / np.sqrt(len(y_val
    val_error_ridge_lambdas[ind_a] = error_val
    # error_val_vec.append(error_val)
    if error_val < min_error_val:
        min_error_val = error_val
        lambda_best = a
        coeffs_ridge_best = clf.coef_
lambda_ridge_vec.append(lambda_best)
y_train_ridge = norm_y_train * np.dot(X_train_norm, coeffs_ridge_best)
y_test_ridge = norm_y_train * np.dot(X_test_norm, coeffs_ridge_best) +
y_2016_ridge = norm_y_train * np.dot(X_2016_norm, coeffs_ridge_best) +
train_error_ridge = np.linalg.norm(y_train - y_train_ridge) / np.sqrt(l
test_error_ridge = np.linalg.norm(y_test - y_test_ridge) / np.sqrt(len(
test_2016_ridge = np.linalg.norm(y_2016 - y_2016_ridge) / np.sqrt(len(y
train_error_ridge_vec.append(train_error_ridge)
val_error_ridge_vec.append(min_error_val)
test_error_ridge_vec.append(test_error_ridge)
```

```
test_2016_ridge_vec.append(test_2016_ridge)
coeffs_ridge_matrix[:,i_m] = coeffs_ridge_best

if n_train == fixed_n:
    coeffs_ridge_fixed = np.copy(coeffs_ridge)
    plt.figure(figsize=(8,6))
    # plt.plot(lambdas_ridge,val_error_lasso_lambdas/10.,marker='o')
    for ind in range(n_features):
        plt.plot(lambdas_ridge,coeffs_ridge[ind,:],color='skyblue')
        plt.xscale('log')
        plt.title('Ridge: n = ' + str(n_train))


# FSR
min_error_val = 1e3
n_features_best_fsr = 0
n_feature = X_train_norm.shape[1]
coeffs_fsr = np.zeros((X_train_norm.shape[1],X_train_norm.shape[1]))
val_error_fsr_lambdas = np.zeros(n_feature)
train_error_fsr_lambdas = np.zeros(n_feature)
for i,a in enumerate(range(1,n_feature)):
    coeffs_fsr = FSR(X_train_norm,y_train_norm,num_features=a)
    y_train_fsr = norm_y_train * np.dot(X_train_norm, coeffs_fsr) + y_t
    y_val_fsr = norm_y_train * np.dot(X_val_norm, coeffs_fsr) + y_train
    error_val = np.linalg.norm(y_val - y_val_fsr) / np.sqrt(len(y_val))
#         error_val_vec.append(error_val)
    if error_val < min_error_val:
        min_error_val = error_val
        n_features_best_fsr = a
        coeffs_fsr_best = coeffs_est

    train_error_fsr_lambdas[i] =  np.linalg.norm(y_train - y_train_fsr
    val_error_fsr_lambdas[i] = error_val
n_features_fsr_vec.append(n_features_best_fsr)

y_train_fsr = norm_y_train * np.dot(X_train_norm, coeffs_fsr_best) + y_

y_train_fsr = norm_y_train * np.dot(X_train_norm, coeffs_fsr_best) + y_
y_test_fsr = norm_y_train * np.dot(X_test_norm, coeffs_fsr_best) + y_tr
y_2016_fsr = norm_y_train * np.dot(X_2016_norm, coeffs_fsr_best) + y_tr
train_error_fsr = np.linalg.norm(y_train - y_train_fsr) / np.sqrt(len(y
test_error_fsr = np.linalg.norm(y_test - y_test_fsr) / np.sqrt(len(y_te
test_2016_fsr = np.linalg.norm(y_2016 - y_2016_fsr) / np.sqrt(len(y_201
train_error_fsr_vec.append(train_error_fsr)
val_error_fsr_vec.append(min_error_val)
test_error_fsr_vec.append(test_error_fsr)
test_2016_fsr_vec.append(test_2016_fsr)

coeffs_fsr_matrix[:,i_m] = coeffs_fsr_best

if n_train == fixed_n:
    plt.figure(figsize=(8,6))
    plt.plot(range(len(train_error_fsr_lambdas)),train_error_fsr_lambda
    plt.plot(range(len(val_error_fsr_lambdas)),val_error_fsr_lambdas,ma
    plt.xlabel(r"Number of features",fontsize=14)
    plt.ylabel('Average error (deg Celsius)',fontsize=14)
    plt.gcf().subplots_adjust(bottom=0.15)
```

```
        plt.legend(loc = 'lower right',fontsize=14)

    i_m = i_m + 1
```

```
Response is CRNH0203-2015-ND_Medora_7_E.txt
Computing regularization path using the lasso...
Computing regularization path using the lasso...
Computing regularization path using the lasso...
Computing regularization path using the lasso...
Computing regularization path using the lasso...
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Computing regularization path using the lasso...
Computing regularization path using the lasso...
Computing regularization path using the lasso...
Computing regularization path using the lasso...
```
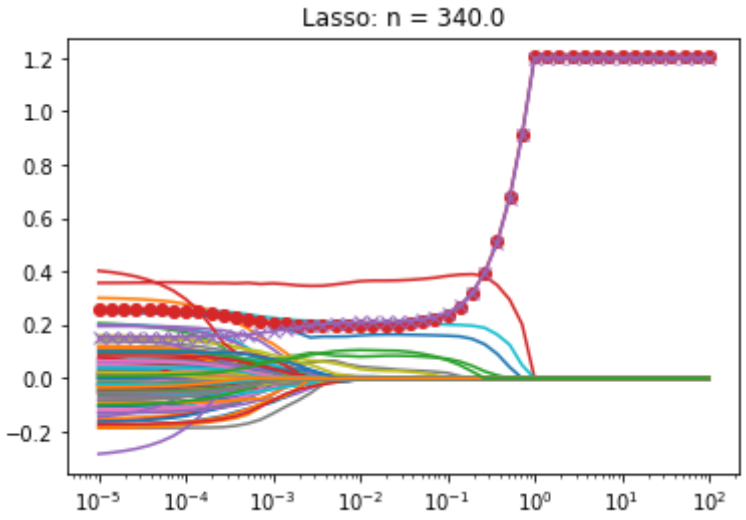
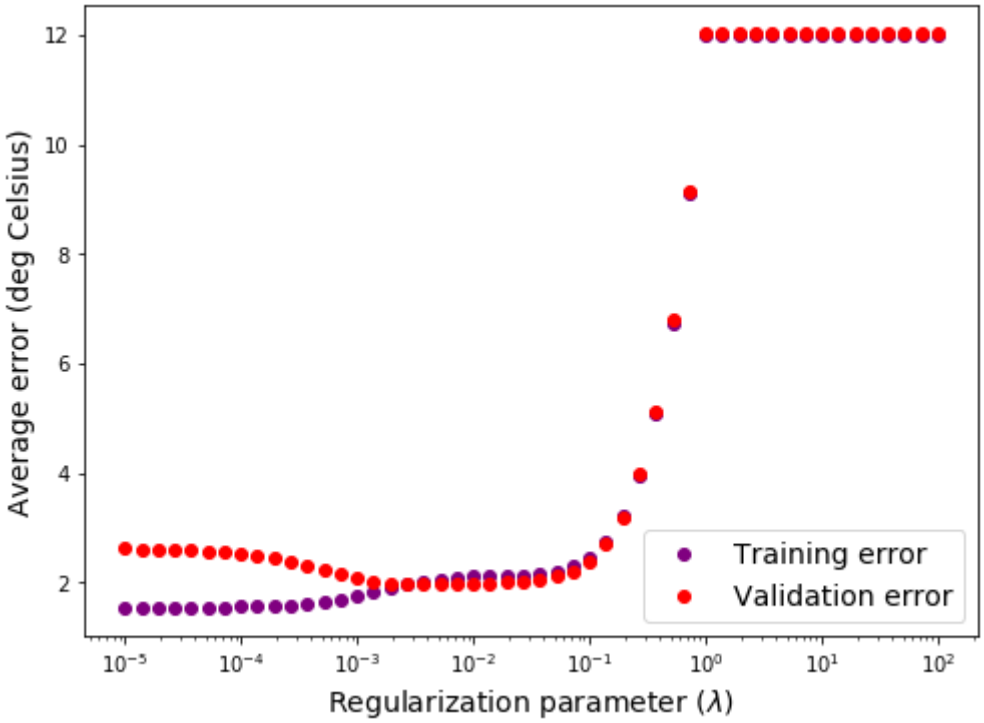
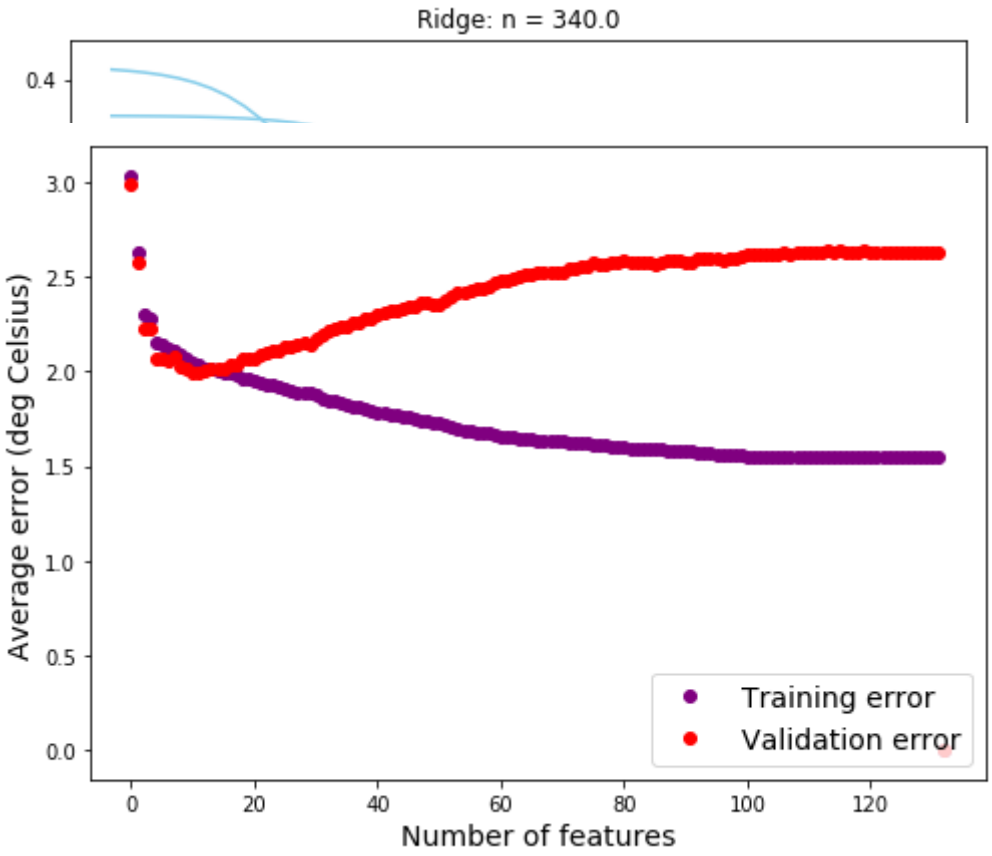


Lasso: n = 340.0
1.2
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 10^{0} 10^{1} 10^{2}


Average error (deg Celsius)
12
10
8
6
4
2
Training error
Validation error
10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 10^{0} 10^{1} 10^{2}
Regularization parameter (λ)

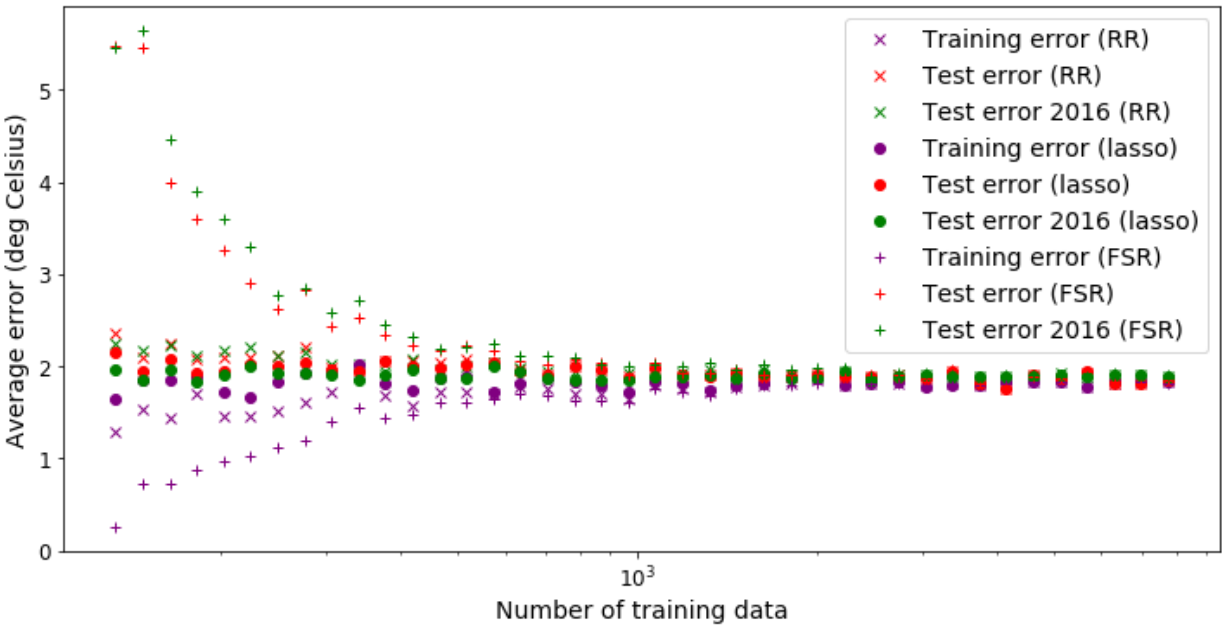

Ridge: n = 340.0
0.4
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Average error (deg Celsius)
0
20
40
60
80
100
120
Number of features
Training error
Validation error

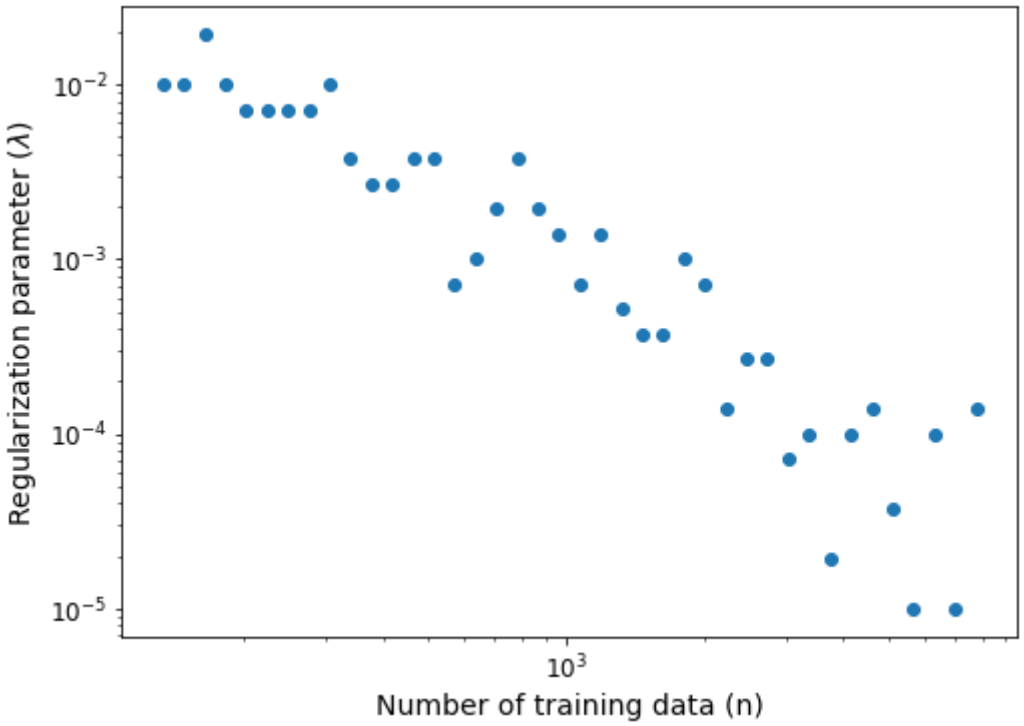
In [9]:

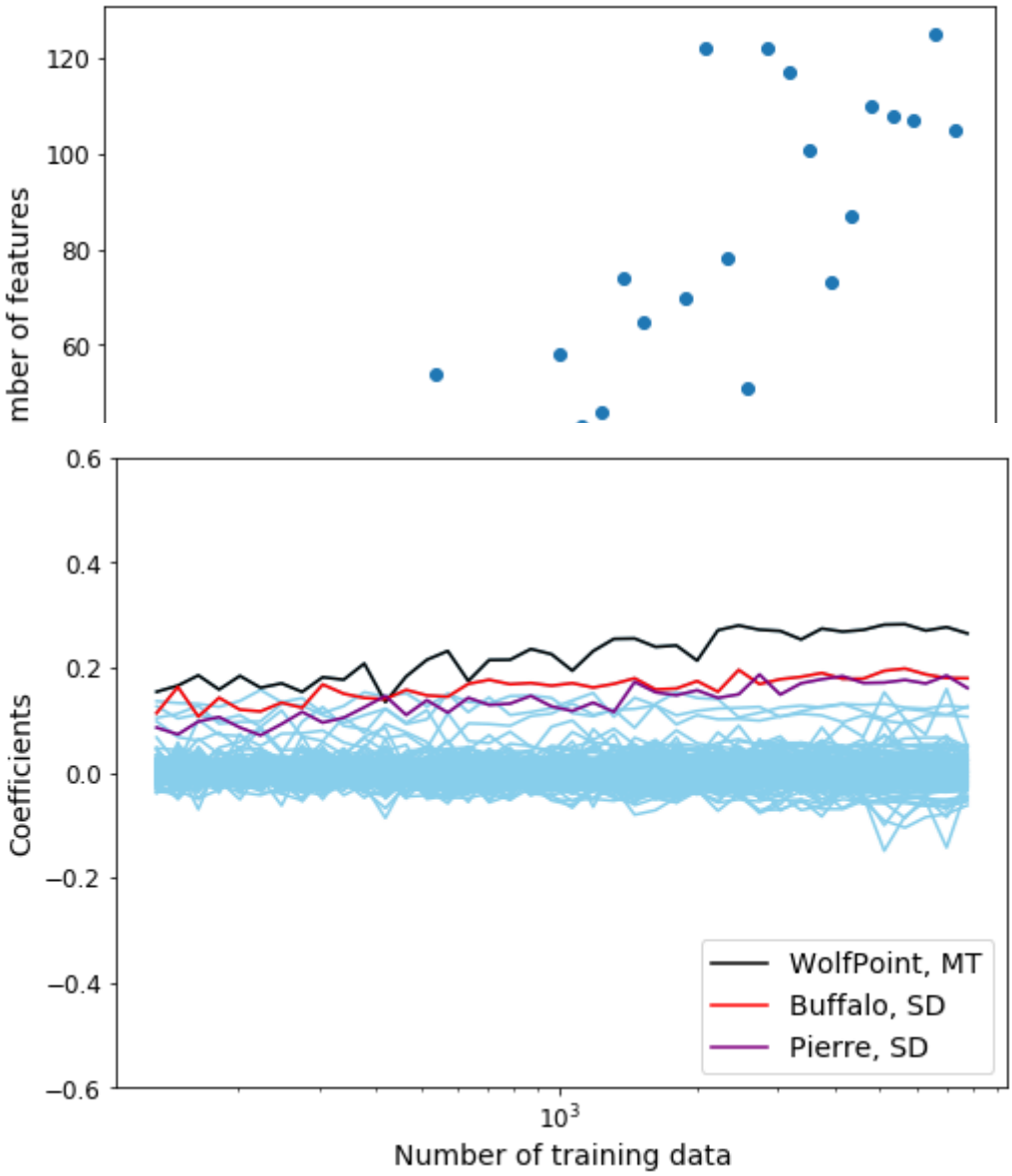
```
xticks=(np.array([200,500,1000,2000,5000]))
xtick_labels = ('200','500','1000','2000','5000')
t.figure(figsize=(12,6))
nstyle = 'None'
t.plot(n_train_list,train_error_ridge_vec,linestyle=linstyle,marker='x',col
t.plot(n_train_list,test_error_ridge_vec,linestyle=linstyle,marker='x',colo
t.plot(n_train_list,test_2016_ridge_vec,linestyle=linstyle,marker='x',color
t.plot(n_train_list,train_error_lasso_vec,linestyle=linstyle,marker='o',col
t.plot(n_train_list,test_error_lasso_vec,linestyle=linstyle,marker='o',colo
t.plot(n_train_list,test_2016_lasso_vec,linestyle=linstyle,marker='o',color
t.plot(n_train_list,train_error_fsr_vec,linestyle=linstyle,marker='+',color
t.plot(n_train_list,test_error_fsr_vec,linestyle=linstyle,marker='+',color=
t.plot(n_train_list,test_2016_fsr_vec,linestyle=linstyle,marker='+',color='
plt.ylim((-0.5,7))
t.xscale('log')
t.xlabel('Number of training data',fontsize=14)
t.ylabel('Average error (deg Celsius)',fontsize=14)
lt.xticks(xticks,xtick_labels)
t.tick_params(labelsize=12)
t.legend(fontsize=14)
t.gcf().subplots_adjust(bottom=0.15)

t.figure(figsize=(8,6))
t.plot(n_train_list,lambda_lasso_vec,marker='o',linestyle='none')
t.xscale('log')
t.yscale('log')
t.ylabel(r"Regularization parameter ($\lambda$)",fontsize=14)
t.xlabel('Number of training data (n)',fontsize=14)
plt.xticks(xticks,xtick_labels)
t.tick_params(labelsize=12)
plt.gcf().subplots_adjust(left=0.2)
t.gcf().subplots_adjust(bottom=0.15)


t.figure(figsize=(8,6))
t.plot(n_train_list,n_features_fsr_vec,marker='o',linestyle='none')
t.xscale('log')
lt.yscale('log')
t.ylabel(r"Number of features",fontsize=14)
t.xlabel('Number of training data (n)',fontsize=14)
plt.xticks(xticks,xtick_labels)
t.tick_params(labelsize=12)
plt.gcf().subplots_adjust(left=0.2)
t.gcf().subplots_adjust(bottom=0.15)


_largest = 3
lor_list = ['black','red','purple','green','orange']
rted_coeffs = np.argsort(np.abs(coeffs_ridge_matrix[:,-1]))
rgest_coeffs = sorted_coeffs[-1:(-n_largest-1):-1]
t.figure(figsize=(8,6))
r ind in range(n_features):
    plt.plot(n_train_list,coeffs_ridge_matrix[ind,:],color='skyblue')
r ind in range(len(largest_coeffs)):
    ind_name = largest_coeffs[ind]
```

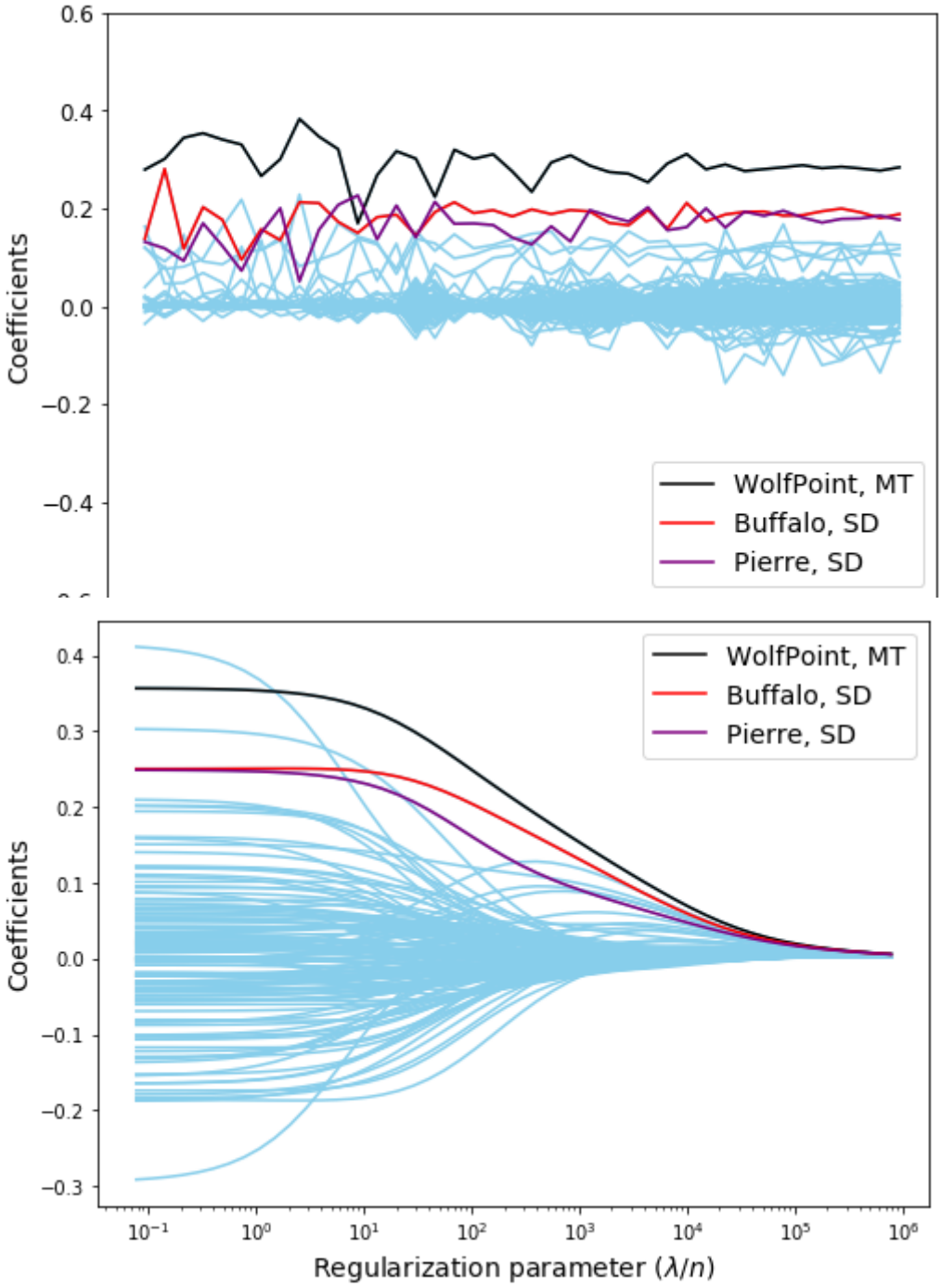
```
    if ind_name>=ind_response:
        ind_name = ind_name + 1
    aux_name = file_name_list[ind_name]
    aux_name = aux_name[14:]
    aux_name = aux_name[:-7]
    table = str.maketrans(dict.fromkeys('_0123456789'))
    aux_name = aux_name.translate(table)
    aux_name = aux_name[2:] + ", " + aux_name[:2]
    plt.plot(n_train_list,coeffs_ridge_matrix[largest_coeffs[ind],:],color=co
.t.ylim((-0.6,0.6))
.t.xscale('log')
.t.xlabel('Number of training data',fontsize=14)
.t.ylabel('Coefficients',fontsize=14)
plt.xticks(xticks,xtick_labels)
.t.tick_params(labelsize=12)
plt.gcf().subplots_adjust(left=0.2)
.t.gcf().subplots_adjust(bottom=0.15)
lt.legend(loc = 'upper right',bbox_to_anchor=(1.3, 1.))
.t.legend(loc = 'lower right',fontsize=14)
ax_name = file_name_list[ind_response]
ax_name = aux_name[14:]
ax_name = aux_name[:-7]
able = str.maketrans(dict.fromkeys('_0123456789'))
ax_name = aux_name.translate(table)
ax_name = aux_name[2:] + ", " + aux_name[:2]
plt.title(aux_name)

rted_coeffs = np.argsort(np.abs(coeffs_lasso_matrix[:,-1]))
rgest_coeffs = sorted_coeffs[-1:(-n_largest-1):-1]
.t.figure(figsize=(8,6))
r ind in range(n_features):
    plt.plot(n_train_list,coeffs_lasso_matrix[ind,:],color='skyblue')
r ind in range(len(largest_coeffs)):
    ind_name = largest_coeffs[ind]
    if ind_name>=ind_response:
        ind_name = ind_name + 1
    aux_name = file_name_list[ind_name]
    aux_name = aux_name[14:]
    aux_name = aux_name[:-7]
    table = str.maketrans(dict.fromkeys('_0123456789'))
    aux_name = aux_name.translate(table)
    aux_name = aux_name[2:] + ", " + aux_name[:2]
    plt.plot(n_train_list,coeffs_lasso_matrix[largest_coeffs[ind],:],color=co
.t.ylim((-0.6,0.6))
.t.xscale('log')
.t.xlabel('Number of training data',fontsize=14)
.t.ylabel('Coefficients',fontsize=14)
plt.xticks(xticks,xtick_labels)
.t.tick_params(labelsize=12)
plt.gcf().subplots_adjust(left=0.2)
.t.gcf().subplots_adjust(bottom=0.15)
lt.legend(loc = 'upper right',bbox_to_anchor=(1.3, 1.))
.t.legend(loc = 'lower right',fontsize=14)
ax_name = file_name_list[ind_response]
ax_name = aux_name[14:]
ax_name = aux_name[:-7]
able = str.maketrans(dict.fromkeys('_0123456789'))
```

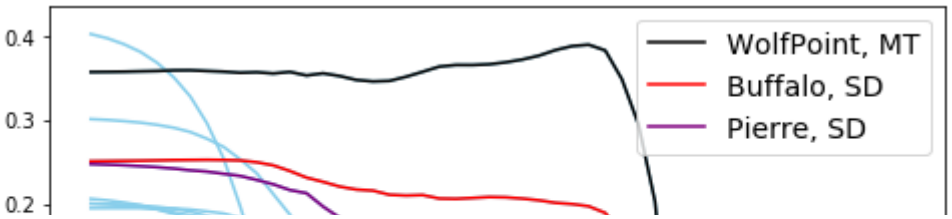
```
ux_name = aux_name.translate(table)
ux_name = aux_name[2:] + ", " + aux_name[:2]
plt.title(aux_name)

lt.figure(figsize=(8,6))
or ind in range(n_features):
    plt.plot(lambdas_ridge,coeffs_ridge_fixed[ind,:],color='skyblue')
    plt.xscale('log')
or ind in range(len(largest_coeffs)):
    ind_name = largest_coeffs[ind]
    if ind_name>=ind_response:
        ind_name = ind_name + 1
    aux_name = file_name_list[ind_name]
    aux_name = aux_name[14:]
    aux_name = aux_name[:-7]
    table = str.maketrans(dict.fromkeys('_0123456789'))
    aux_name = aux_name.translate(table)
    aux_name = aux_name[2:] + ", " + aux_name[:2]
    plt.plot(lambdas_ridge,coeffs_ridge_fixed[largest_coeffs[ind],:],color=co
lt.xlabel(r"Regularization parameter ($\lambda/n$)",fontsize=14)
lt.ylabel('Coefficients',fontsize=14)
lt.gcf().subplots_adjust(bottom=0.15)
lt.legend(loc = 'upper right',fontsize=14)
lt.xscale('log')

lt.figure(figsize=(8,6))
or ind in range(n_features):
    plt.plot(lambdas_lasso,coeffs_lasso_fixed[ind,:],color='skyblue')
    plt.xscale('log')
or ind in range(len(largest_coeffs)):
    ind_name = largest_coeffs[ind]
    if ind_name>=ind_response:
        ind_name = ind_name + 1
    aux_name = file_name_list[ind_name]
    aux_name = aux_name[14:]
    aux_name = aux_name[:-7]
    table = str.maketrans(dict.fromkeys('_0123456789'))
    aux_name = aux_name.translate(table)
    aux_name = aux_name[2:] + ", " + aux_name[:2]
    plt.plot(lambdas_lasso,coeffs_lasso_fixed[largest_coeffs[ind],:],color=co
lt.xlabel(r"Regularization parameter ($\lambda/n$)",fontsize=14)
lt.ylabel('Coefficients',fontsize=14)
lt.gcf().subplots_adjust(bottom=0.15)
lt.legend(loc = 'upper right',fontsize=14)
lt.xscale('log')
```


Training error (RR)
Test error (RR)
Test error 2016 (RR)
Training error (lasso)
Test error (lasso)
Test error 2016 (lasso)
Training error (FSR)
Test error (FSR)
Test error 2016 (FSR)
Average error (deg Celsius)
0
1
2
3
4
5
10^3
Number of training data


Regularization parameter (λ)
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^3
Number of training data (n)


mber of features
120
100
80
60
Coefficients
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
WolfPoint, MT
Buffalo, SD
Pierre, SD
10^3
Number of training data


Coefficients
WolfPoint, MT
Buffalo, SD
Pierre, SD
Coefficients
WolfPoint, MT
Buffalo, SD
Pierre, SD
Regularization parameter (λ/n)



In [ ]: