In [1]:

```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import matplotlib.dates as mdates
from spi_class import *
from scipy import stats
import seaborn as sns
```

In [2]:

```
'''
prec_data = pd.read_csv('./data/rehana_rf/t1.csv')
prec_data.fillna(0)
prec_data['Prec'] = prec_data[['Prec_Daddi']].max(axis=1)
final_prec = prec_data
final_prec['Date'] = pd.to_datetime(final_prec['Date'], format="%Y-%m-%d")
final_prec = final_prec.set_index('Date')
'''
```

Out[2]:

```
'\nprec_data = pd.read_csv(\'./data/rehana_rf/t1.csv\')\nprec_data.fillna(0)\nprec_data[\
'Prec\'] = prec_data[[\'Prec_Daddi\']].max(axis=1)\nfinal_prec = prec_data\nfinal_prec[\'
Date\'] = pd.to_datetime(final_prec[\'Date\'], format="%Y-%m-%d")\nfinal_prec = final_pre
c.set_index(\'Date\')\n'
```

Read precipitaiton data

In [4]:

```
def convert(prec_data, count):
    temp = pd.DataFrame()
    for index, row in prec_data.iterrows():
        final_prec = pd.DataFrame(columns=['Prec'+str(count)])
        #print(len(row)-row.isnull().sum()+1 )
        final_prec = pd.concat([final_prec, pd.DataFrame(row.values[2:], columns=['Prec'
+str(count)])], axis=0)
        final_prec.insert(1, "Month", row.values[1])
        final_prec.insert(1, "Year", row.values[0])
        final_prec['Day'] = list(range(1, len(row)-1))
        temp = pd.concat([temp,final_prec], axis=0)
    temp.dropna(subset = ["Prec"+str(count)], inplace=True)
    #temp.to_csv("temp.csv")
    return temp

temp1 = convert(pd.read_csv('./cluster-3/hatkanangale.csv', header=None), 1)
temp2 = convert(pd.read_csv('./cluster-3/kagal.csv', header=None), 2)
temp3 = convert(pd.read_csv('./cluster-3/karveer.csv', header=None), 3)
temp4 = convert(pd.read_csv('./cluster-3/kolhapur.csv', header=None), 4)
temp5 = convert(pd.read_csv('./cluster-3/panhala.csv', header=None), 5)
temp6 = convert(pd.read_csv('./cluster-3/radhanagari.csv', header=None), 6)
temp7 = convert(pd.read_csv('./cluster-3/sadalga.csv', header=None), 7)
```

In [5]:

```
date1 = '1980-01-01'
date2 = '2012-11-12'
mydates = pd.date_range(date1, date2).tolist()
cd=pd.DataFrame(mydates)
cd.columns = ['Date']
cd['Year'] = pd.DatetimeIndex(cd['Date']).year
cd['Month']=pd.DatetimeIndex(cd['Date']).month
cd['Day']=pd.DatetimeIndex(cd['Date']).day
```

Merge precipitaiton data from different nearby stations

In [6]:

```
cd = pd.merge(cd, temp1, how='left', left_on = ['Month','Year','Day'], right_on = ['Month','Year','Day'])
cd = pd.merge(cd, temp2, how='left', left_on = ['Month','Year','Day'], right_on = ['Month','Year','Day'])
cd = pd.merge(cd, temp3, how='left', left_on = ['Month','Year','Day'], right_on = ['Month','Year','Day'])
cd = pd.merge(cd, temp4, how='left', left_on = ['Month','Year','Day'], right_on = ['Month','Year','Day'])
cd = pd.merge(cd, temp5, how='left', left_on = ['Month','Year','Day'], right_on = ['Month','Year','Day'])
cd = pd.merge(cd, temp6, how='left', left_on = ['Month','Year','Day'], right_on = ['Month','Year','Day'])
cd = pd.merge(cd, temp7, how='left', left_on = ['Month','Year','Day'], right_on = ['Month','Year','Day'])
```

In [7]:

```
cd.head()
```

Out[7]:

	Date	Year	Month	Day	Prec1	Prec2	Prec3	Prec4	Prec5	Prec6	Prec7
0	1980-01-01	1980	1	1	0.0	0.0	NaN	0.0	0.0	0.0	NaN
1	1980-01-02	1980	1	2	0.0	0.0	NaN	0.0	0.0	0.0	NaN
2	1980-01-03	1980	1	3	0.0	0.0	NaN	0.0	0.0	0.0	NaN
3	1980-01-04	1980	1	4	0.0	0.0	NaN	0.0	0.0	0.0	NaN
4	1980-01-05	1980	1	5	0.0	0.0	NaN	0.0	0.0	0.0	NaN

In [8]:

```
cd.fillna(0, inplace=True)
cd['Prec'] = cd[['Prec1', 'Prec2', 'Prec3', 'Prec4', 'Prec5', 'Prec6', 'Prec7']].max(axis=1)
final_prec = cd
final_prec['Date'] = pd.to_datetime(final_prec['Date'], format="%Y-%m-%d")
final_prec = final_prec.set_index('Date')
final_prec.shape
```

Out[8]:

```
(12005, 11)
```

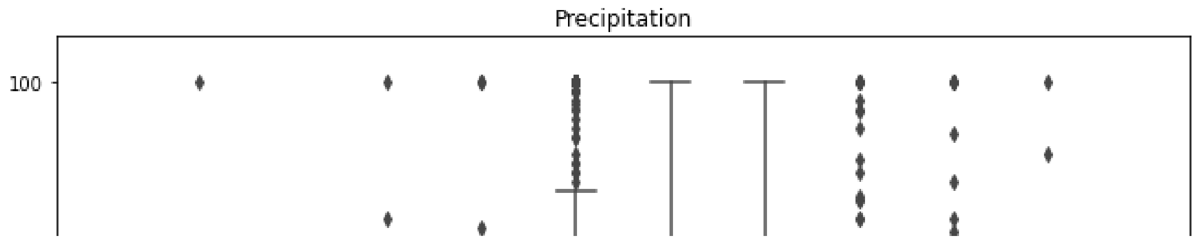
Precipitation trend for each month based on box-plot

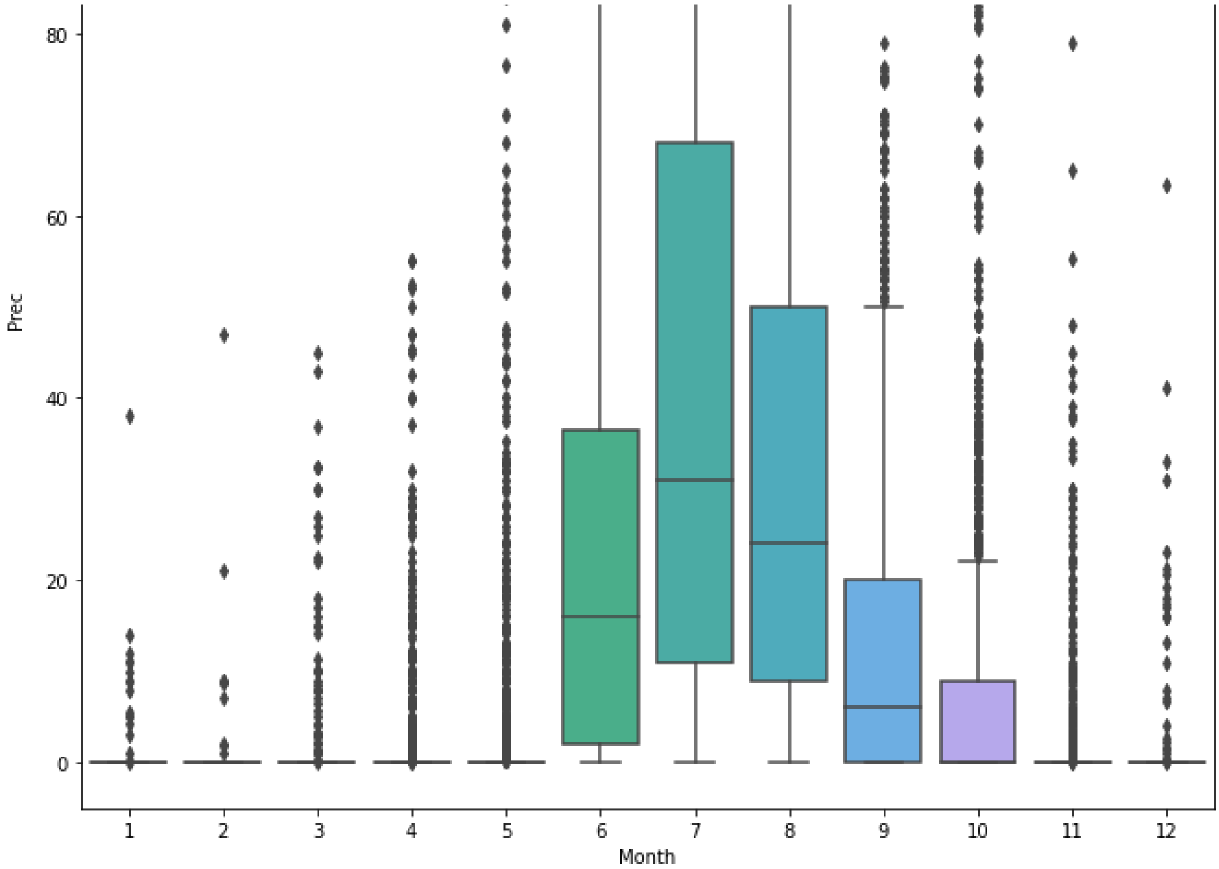
In [43]:

```
final_prec['Year'] = final_prec.index.year
final_prec['Month'] = final_prec.index.month
fig, axes = plt.subplots(1, 1, figsize=(11, 10), sharex=True)
sns.boxplot(data=final_prec, x='Month', y='Prec', ax=axes)
axes.set_title('Precipitation')
```

Out[43]:

```
Text(0.5, 1.0, 'Precipitation')
```





Convert to monthly precipitaiton data

In [11]:

```
#weekly_prec = final_prec[['Prec']].resample('W').sum()
monthly_prec = final_prec[['Prec']].resample('M').sum()
#weekly_prec.shape
```

Functions for computing drought index using spi_class, plotting drought indices

In [12]:

```
def create_datelist(start_date, n_months):

    dates = [start_date + relativedelta(months=i) for i in range(0, n_months)]

    return np.array(dates)

def plot_index(time, data, save_file=None, index_type='SPI'):

    b_width = 22
    pos_inds = np.where(data >= 0.)[0]
    neg_inds = np.where(data < 0.)[0]

    data = np.squeeze(data)

    fig, ax = plt.subplots()
    ax.bar(time[pos_inds], data[pos_inds], width=b_width, align='center', color='b')
    ax.bar(time[neg_inds], data[neg_inds], width=b_width, align='center', color='r')
    ax.grid(True)
    ax.set_xlabel("Date")
    ax.set_ylabel(index_type)

    if save_file:
        plt.savefig(save_file, dpi=400)
    else:
        plt.show()

def pearsonr_ci(x,y,alpha=0.05):
    r, p = stats.pearsonr(x,y)
    r_z = np.arctanh(r)
    se = 1/np.sqrt(x.size-3)
    z = stats.norm.ppf(1-alpha/2)
    lo_z, hi_z = r_z-z*se, r_z+z*se
    lo, hi = np.tanh((lo_z, hi_z))
    return r, p, lo, hi

def calc_index(df, timescale, distribution, start_date, col_name, plot=False):
    df=pd.DataFrame(df)
    data=np.array(df)

    df.columns = ['Prec']

    #spi_timescale = 4 #4 #8 #4
    X_scale_prec = df['Prec'].rolling(timescale).mean()
    X_np_prec = X_scale_prec.to_numpy()


    df_shape = X_scale_prec.shape
    X_np_prec = X_np_prec[~np.isnan(X_np_prec)]

    spi = SPI()

    spi.set_rolling_window_params(
        span=1, window_type=None, center=True
    )

    # Set distribution parameters
    spi.set_distribution_params(dist_type=distribution)   #'exp'

    # Calculate SPI
    data_prec,score_prec,par_prec = spi.calculate(X_np_prec, starting_month=1)

    #print("Score: ", score_prec)

    X2_prec=data_prec.flatten()

    for i in range(len(df)-len(data_prec)): #len(weekly_prec)-len(data_prec) len(final_prec)-len(data_prec)
        X2_prec=np.concatenate([[0],X2_prec])

    X2_prec[X2_prec==np.inf] = 1.0
    X2_prec[X2_prec==-np.inf] = -1.0
    #print("Data shape: ", X2_prec.shape)
    X2_prec[X2_prec>3] = 3.0
    X2_prec[X2_prec<-3] = -3.0
    spi_dateIndex = pd.DataFrame(X2_prec, columns =[col_name])
    spi_dateIndex['Date'] = pd.date_range(start=start_date, periods=len(X2_prec), freq='M') # freq='W', start='1-12-1966'
    spi_dateIndex = spi_dateIndex.set_index('Date')

    if plot:
        plot_index(spi_dateIndex.index, X2_prec, index_type=col_name)

    return spi_dateIndex, X2_prec
```

Read discharge data

In [13]:

```
dis_data = pd.read_excel('./KRB_Discharge_Stations/Discharge/Vandur_SUMQH.xls') #Daddi_SUMQH.xls
```

Convert to monthly discharge data

In [14]:

```
#dis_data['Discharge'].fillna(dis_data['Discharge'].mean(), inplace=True)
```

```
#dis_data['Discharge'].fillna(0, inplace=True)
#dis_data.loc[dis_data['Discharge'] > 100.0, 'Discharge'] = 100.0
dis_data = dis_data.set_index('Date')
monthly_dis = dis_data[['Discharge']].resample('M').sum()
#weekly_dis = dis_data[['Discharge']].resample('W').sum()
#weekly_dis.to_csv("weekly_runoff_bagalkot.csv", index=True)
```

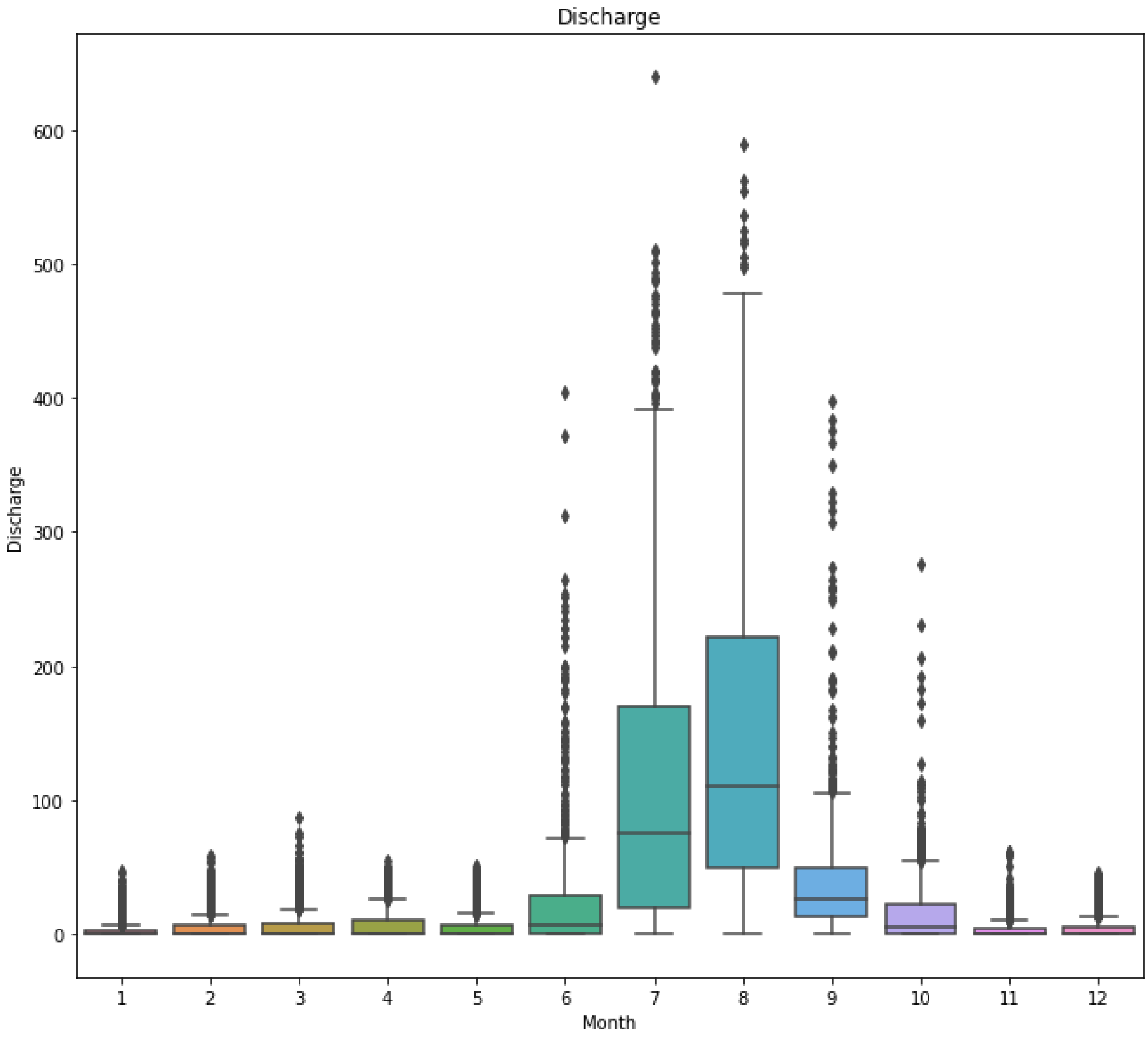
Discharge trend for each month based on box-plot

In [15]:

```
dis_data['Year'] = dis_data.index.year
dis_data['Month'] = dis_data.index.month
fig, axes = plt.subplots(1, 1, figsize=(11, 10), sharex=True)
sns.boxplot(data=dis_data, x='Month', y='Discharge', ax=axes)
axes.set_title('Discharge')
```

Out[15]:

```
Text(0.5, 1.0, 'Discharge')
```



Perform following:

- **Compute SPI and SRI for all monthly scales ranging from 1-month to 12-month**
- **For each combination of monthly scale, compute pearson correlation and p value.**
- **Plot heatmap for all combinations**

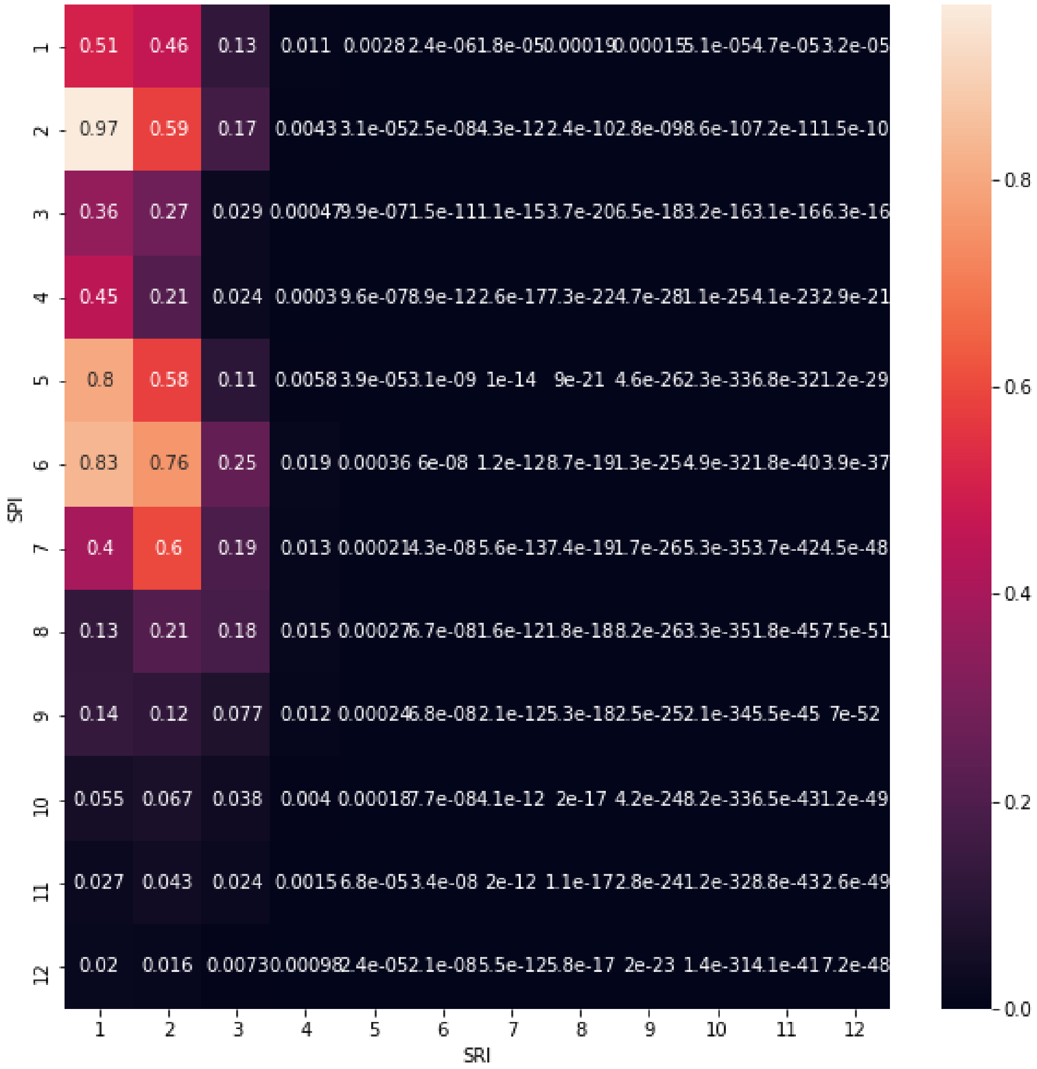
Result: For the selected cluster, we got highest correlation for scale of 1-month SPI and 2-month SRI.

In [16]:

```
scale = list(range(1,13))

p_mat = []
for i in scale:
    p_arr = []
    for j in scale:
        spi_dateIndex, X2_prec = calc_index(monthly_prec['Prec'], i, 'wei', '1-1-1980',
'spi')
        sri_dateIndex, X2_dis = calc_index(monthly_dis['Discharge'], j, 'gev', '1-6-1979
', 'sri')
        r, p, lo, hi = pearsonr_ci(sri_dateIndex.loc['1980-01':sri_dateIndex.index[-1],
'sri'],
                                   spi_dateIndex.loc['1980-01':sri_dateIndex.index[-1],
'spi'])
        p_arr.append(p)
    p_mat.append(p_arr)
#print(p_mat)

f, ax = plt.subplots(figsize=(10, 10))
ax = sns.heatmap(p_mat, annot=True, xticklabels=scale, yticklabels=scale)
ax.set_xlabel('SRI')
ax.set_ylabel('SPI')
```

Out[16]:

```
Text(69.0, 0.5, 'SPI')
```

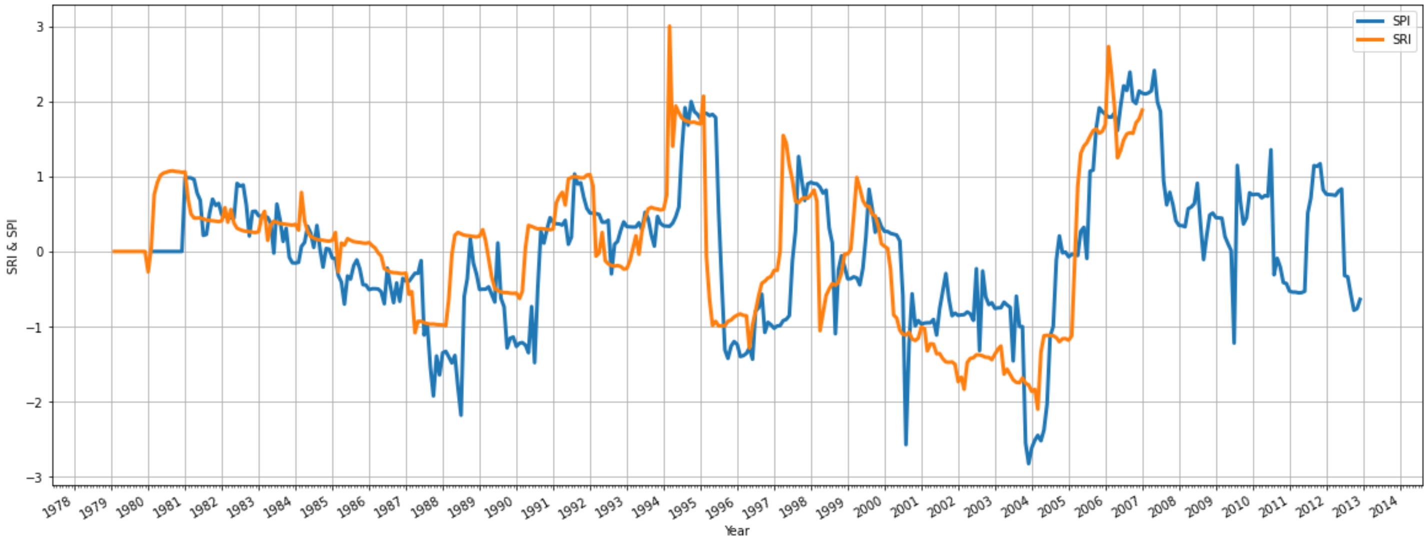


Combined plot of SPI and SRI at 12-month scale

In [18]:

```
spi_dateIndex, X2_prec = calc_index(monthly_prec['Prec'], 12, 'wei', '1-1-1980', 'spi')
sri_dateIndex, X2_dis = calc_index(monthly_dis['Discharge'], 12, 'gev', '1-6-1979', 'sri
')
```

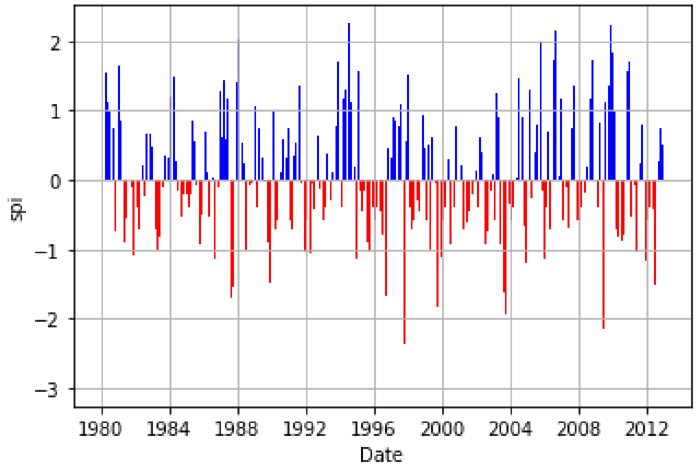
```
fig, ax = plt.subplots()
fig.set_size_inches(20,8)
#ax.plot(daily_discharge['Discharge'], marker='.', markersize=2, color='0.6',
#linestyle='None', label='Daily')
#ax.plot(discharge_7d['Discharge'], linewidth=2, label='7-d Rolling Mean')
ax.plot(spi_dateIndex.index, spi_dateIndex['spi'], linewidth=3, label='SPI')
ax.plot(sri_dateIndex.index,sri_dateIndex['sri'], linewidth=3, label='SRI')
# Set x-ticks to yearly interval and add legend and labels
ax.xaxis.set_major_locator(mdates.YearLocator())
ax.xaxis.set_major_formatter(mdates.DateFormatter('%Y'))
ax.xaxis.set_minor_locator(mdates.MonthLocator())
ax.legend()
ax.set_xlabel('Year')
ax.set_ylabel('SRI & SPI')

ax.format_xdata = mdates.DateFormatter('%Y-%m-%d')
ax.format_ydata = lambda x: '$%1.2f' % x  # format the price.
ax.grid(True)
fig.autofmt_xdate()
```

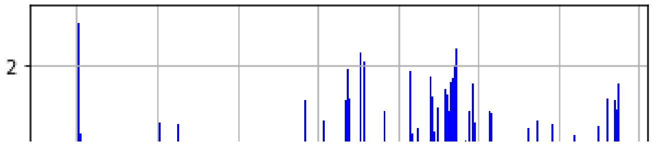


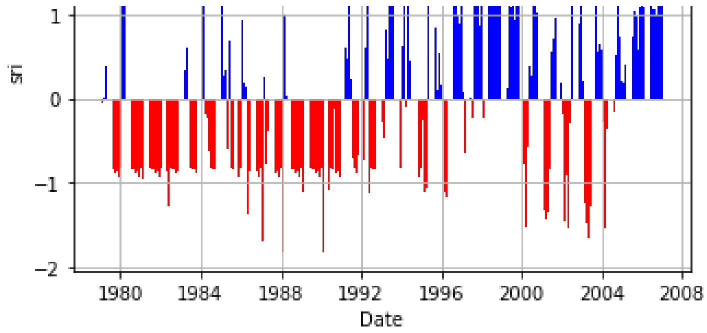
Below we compute SPI and SRI at scale of highest correlation i.e 2-month SPI and 1-month SRI

In [21]:

```
spi_dateIndex, X2_prec = calc_index(monthly_prec['Prec'], 2, 'wei', '1-1-1980', 'spi', p
lot=True)
sri_dateIndex, X2_dis = calc_index(monthly_dis['Discharge'], 1, 'gev', '1-6-1979', 'sri'
, plot=True)
```







In [90]:

```
'''
f, ax = plt.subplots(figsize=(20, 10))
ax.plot(monthly_prec.index, X2_prec, label='SPI, Scale=2')
ax.plot(monthly_dis.index, X2_dis, label='SRI, Scale=1')
#plt.plot(weekly_prec.index, X2_prec)
#plt.plot(weekly_dis.index, X2_dis)
ax.legend()
ax.grid(True)
'''
```

Save the computed SPI and SRI

In [22]:

```
import csv
df_spi = pd.DataFrame()
df_spi['date'] = pd.date_range(start='1-1-1980', periods=len(X2_prec), freq='D') #'1-1-1
980'
df_spi['discharge'] = X2_prec
df_spi.to_csv('./cluster-3/spi_cluster3.csv', index=False)
```

In [23]:

```
df_sri = pd.DataFrame()
df_sri['date'] = pd.date_range(start='1-6-1979', periods=len(X2_dis), freq='D') # '1-12-
1978'
df_sri['discharge'] = X2_dis
df_sri.to_csv('./cluster-3/sri_cluster3.csv', index=False)
```

In [35]:

```
spi_pool = pd.read_csv("./cluster-3/spi_pool.csv")
spi_summ = pd.read_csv("./cluster-3/spi_summary.csv")
sri_pool = pd.read_csv("./cluster-3/sri_pool.csv")
sri_summ = pd.read_csv("./cluster-3/sri_summary.csv")
```

In [36]:

```
import datetime

col_list=['start', 'time', 'end']
scale = 31 #7
spi_summ[col_list] = spi_summ[col_list].apply(pd.to_datetime) #pd.to_datetime(spi_summ[co
l_list]).dt.date("%Y-%m-%d")
sri_summ[col_list] = sri_summ[col_list].apply(pd.to_datetime) #pd.to_datetime(sri_summ[co
l_list]).dt.date
spi_start_date = datetime.datetime(1980,1,1) #datetime.datetime(1980,1,1)
sri_start_date = datetime.datetime(1979,1,6) #datetime.datetime(1978,12,1)

spi_summ['start'] = (spi_summ['start'] + (spi_summ['start']-spi_start_date - datetime.ti
medelta(days=1))*scale + (spi_summ['start']-spi_start_date) // 2).dt.date #-datetime.tim
edelta(days=1)
spi_summ['end'] = (spi_summ['end'] + (spi_summ['end']-spi_start_date - datetime.timedelta
(days=1))*scale + (spi_summ['end']-spi_start_date) // 2).dt.date #-datetime.timedelta(da
ys=1)
```

```
spi_summ['duration'] = spi_summ['end'] - spi_summ['start']
spi_summ.drop(['time', 'volume', 'dbt', 'qmin', 'tqmin'], axis=1, inplace=True)
sri_summ['start'] = (sri_summ['start'] + (sri_summ['start']-sri_start_date + datetime.timedelta(days=3))*scale + (sri_summ['start']-sri_start_date) // 2).dt.date #-datetime.timedelta(days=1)
sri_summ['end'] = (sri_summ['end'] + (sri_summ['end']-sri_start_date + datetime.timedelta(days=3))*scale + (sri_summ['end']-sri_start_date) // 2).dt.date #-datetime.timedelta(days=1)
sri_summ['duration'] = sri_summ['end'] - sri_summ['start']
sri_summ.drop(['time', 'volume', 'dbt', 'qmin', 'tqmin'], axis=1, inplace=True)
```

In [37]:

```
spi_summ = spi_summ.set_index('start')
spi_summ.head(n=15)
```

Out[37]:

	Unnamed: 0	event.no	end	duration
start				
1983-02-13	8	8	1983-06-23	130 days
1984-10-22	12	12	1985-07-09	260 days
1985-10-15	14	14	1986-03-26	162 days
1987-11-01	17	17	1988-03-10	130 days
1990-01-22	23	23	1990-07-03	162 days
1992-05-16	28	28	1993-03-04	292 days
1996-02-10	35	35	1996-08-23	195 days
1997-05-10	37	37	1997-09-17	130 days
1999-03-23	40	40	1999-11-06	228 days
2001-03-07	44	44	2001-12-25	293 days
2002-07-08	47	47	2003-03-25	260 days
2003-12-10	50	50	2004-07-24	227 days
2004-10-30	53	53	2005-10-22	357 days
2012-02-16	68	68	2012-08-29	195 days
2013-01-06	69	69	2013-05-16	130 days

In [38]:

```
sri_summ = sri_summ.set_index('start')
sri_summ.head(n=15)
```

Out[38]:

	Unnamed: 0	event.no	end	duration
start				
1979-07-15	2	2	1980-03-31	260 days
1980-09-10	3	3	1981-05-28	260 days
1981-10-05	4	4	1982-05-20	227 days
1982-09-27	5	5	1983-06-14	260 days
1983-11-24	6	6	1984-07-08	227 days
1984-10-14	7	7	1985-08-02	292 days
1986-02-13	9	9	1986-08-27	195 days
1987-01-04	10	10	1988-11-17	683 days
1989-04-28	12	12	1991-01-06	618 days

	Unnamed: 0	event.no	end	duration
start				
1991-05-16	14	14	1991-12-29	227 days
1993-07-04	17	17	1994-04-22	292 days
1995-11-28	20	20	1996-07-13	228 days
2002-10-05	29	29	2003-02-12	130 days
2003-10-30	30	30	2004-03-08	130 days
2004-12-25	31	31	2005-06-06	163 days

Below we calculate lag time for the found drought events

In [39]:

```
#final_prec['lagtime'] = 0
#weekly_prec['lagtime'] = 0
drought_event_pairs = pd.DataFrame(columns = ['Meteorological_drought_beg_date', 'Meteoro
logical_drought_end_date',
                                              'Hydrological_drought_beg_date', 'Hydrolog
ical_drought_end_date','Days'])
monthly_prec['lagtime'] = 0
for index, row in spi_summ.iterrows():
    idx = sri_summ.index.searchsorted(index)
    if idx >= sri_summ.shape[0]:
        #print("sri out-of-range")
        continue
    sri_idx = sri_summ.index[idx]
    #lis.append(sri_summ.loc[sri_summ.index[idx]])
    '''
    if spi_summ.loc[index]['end'] < sri_summ.index[idx]:
        continue;
    '''
    start = index
    end = sri_summ.loc[sri_idx]['end']
    #final_prec.loc[start:end, 'lagtime'] = (sri_summ.index[idx]-index).days
    monthly_prec.loc[start:end, 'lagtime'] = (sri_summ.index[idx]-index).days
    a_series = pd.Series([start, end, sri_idx, sri_summ.loc[sri_idx, 'end'], (sri_summ.i
ndex[idx]-index).days], index = drought_event_pairs.columns)
    drought_event_pairs = drought_event_pairs.append(a_series, ignore_index=True)

drought_event_pairs.to_csv("./cluster-3/drought_event_pairs.csv", index=False)
drought_event_pairs.head(n=15)
```

Out[39]:

	Meteorological_drought_beg_date	Meteorological_drought_end_date	Hydrological_drought_beg_date	Hydrological_drought_e
0	1983-02-13	1984-07-08	1983-11-24	19
1	1984-10-22	1986-08-27	1986-02-13	19
2	1985-10-15	1986-08-27	1986-02-13	19
3	1987-11-01	1991-01-06	1989-04-28	19
4	1990-01-22	1991-12-29	1991-05-16	19
5	1992-05-16	1994-04-22	1993-07-04	19
6	1996-02-10	2003-02-12	2002-10-05	20
7	1997-05-10	2003-02-12	2002-10-05	20
8	1999-03-23	2003-02-12	2002-10-05	20
9	2001-03-07	2003-02-12	2002-10-05	20
10	2002-07-08	2003-02-12	2002-10-05	20
11	2003-12-10	2005-06-06	2004-12-25	20
12	2004-10-30	2005-06-06	2004-12-25	20

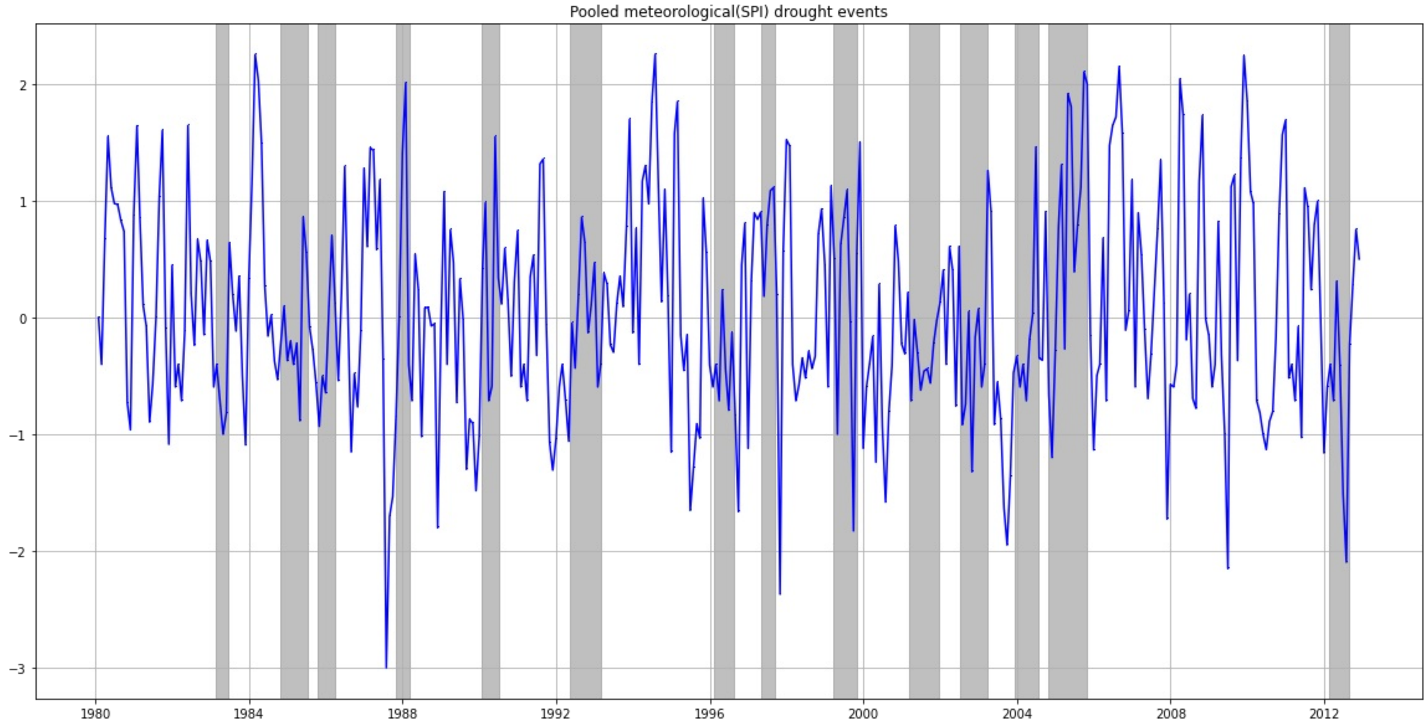
In [200]:

In [200]:

```
#monthly_prec.to_csv("./data/cluster-3/spi_lagtime.csv", index=True) #weekly_prec
```

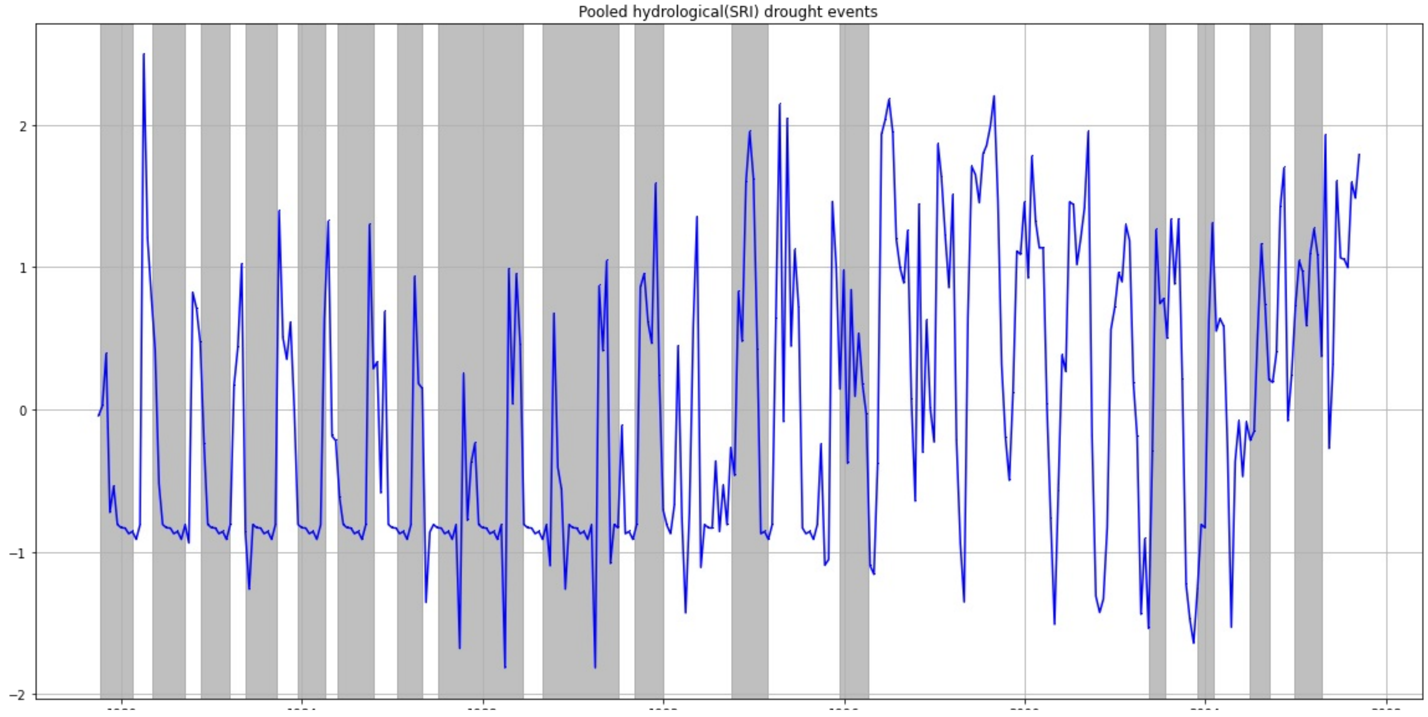
In [48]:

```
plt.figure(figsize=(20,10))
plt.plot(monthly_prec.index, spi_pool['discharge'], linestyle='-', marker=',', color='b'
)
plt.title("Pooled meteorological(SPI) drought events")
plt.grid(True)
for index, row in spi_summ.iterrows():
    if index <monthly_prec.index[-1]:
        plt.axvspan(index, index + row[3], alpha=0.5, color='gray')
```


Pooled meteorological(SPI) drought events

In [49]:

```
plt.figure(figsize=(20,10))
plt.plot(monthly_dis.index, sri_pool['discharge'], linestyle='-', marker=',', color='b')
plt.title("Pooled hydrological(SRI) drought events")
plt.grid(True)
for index, row in sri_summ.iterrows():
    if index < monthly_dis.index[-1]:
        plt.axvspan(index, index + row[3], alpha=0.5, color='gray')
```


Pooled hydrological(SRI) drought events

In [ ]: