

investigating-a-vix-trading-signal

March 22, 2025

1 Investigating Vix Levels And Returns

1.1 Python Imports

```
[1]: # Standard Library
import os
import sys
import datetime
import random
import warnings

# Data Handling
import pandas as pd
import numpy as np

# Data Visualization
import matplotlib.pyplot as plt
import matplotlib.dates as mdates
import seaborn as sns
import dataframe_image as dfi

from matplotlib.ticker import FuncFormatter, FormatStrFormatter, MultipleLocator

# Data Sources
import yfinance as yf

# Statistical Analysis
import statsmodels.api as sm
from sklearn.decomposition import PCA
from sklearn.preprocessing import StandardScaler

# Suppress warnings if needed
# warnings.filterwarnings("ignore")
```

1.2 Set Base Directory

```
[2]: # Add the base directory to the system path
base_directory = "/home/jared/Cloud_Storage/Dropbox/Quant_Finance_Research"
sys.path.append(base_directory)
```

1.3 Import Functions

```
[3]: # TBD
```

1.4 Python Functions

```
[4]: # This function pulls data from Yahoo finance
def yf_data_updater(fund):

    # Download data from YF
    df_comp = yf.download(fund)

    # Drop the column level with the ticker symbol
    df_comp.columns = df_comp.columns.droplevel(1)

    # Reset index
    df_comp = df_comp.reset_index()

    # Remove the "Price" header from the index
    df_comp.columns.name = None

    # Reset date column
    df_comp['Date'] = df_comp['Date'].dt.tz_localize(None)

    # Set 'Date' column as index
    df_comp = df_comp.set_index('Date', drop=True)

    # Drop data from last day because it's not accurate until end of day
    df_comp = df_comp.drop(df_comp.index[-1])

    # Export data to excel
    file = fund + ".xlsx"
    df_comp.to_excel(file, sheet_name='data')

    print(f"The first and last date of data for {fund} is: ")
    print(df_comp[:1])
    print(df_comp[-1:])
    print(f>Data updater complete for {fund} data")

    return print(f"-----")
```

```
[5]: # Set number of decimal places in pandas
def dp(decimal_places):
    pd.set_option('display.float_format', lambda x: f'%.{decimal_places}f' % x)
```

```
[6]: def load_data(file):
    # Import CSV
    try:
        df = pd.read_csv(file)
    except:
        pass

    # Import excel
    try:
        df = pd.read_excel(file, sheet_name='data', engine='openpyxl')
    except:
        pass

    return df
```

```
[7]: # The `df_info` function returns some useful information about
# a dataframe, such as the columns, data types, and size.

def df_info(df):
    print('The columns, shape, and data types are:')
    print(df.info())
    print('The first 5 rows are:')
    display(df.head())
    print('The last 5 rows are:')
    display(df.tail())
```

1.5 Import Data

1.5.1 CBOE Volatility Index (VIX)

```
[8]: yf_data_updater('^VIX')
```

```
YF.download() has changed argument auto_adjust default to True
[*****100%*****] 1 of 1 completed

The first and last date of data for ^VIX is:
      Close  High   Low  Open  Volume
Date
1990-01-02  17.24  17.24  17.24  17.24      0
      Close  High      Low  Open  Volume
Date
2025-03-20  19.799999  21.17  19.299999  19.52      0
Data updater complete for ^VIX data
-----
```

```
[9]: dp(2)
```

```
[10]: # VIX
vix = load_data('~VIX.xlsx')

# Set 'Date' column as datetime
vix['Date'] = pd.to_datetime(vix['Date'])

# Drop 'Volume'
vix.drop(columns = {'Volume'}, inplace = True)

# Set Date as index
vix.set_index('Date', inplace = True)
```

```
[11]: # Check to see if there are any NaN values
vix[vix['High'].isna()]
```

```
[11]: Empty DataFrame
Columns: [Close, High, Low, Open]
Index: []
```

```
[12]: # Forward fill to clean up missing data
vix['High'] = vix['High'].ffill()
```

```
[13]: df_info(vix)
```

```
The columns, shape, and data types are:
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 8870 entries, 1990-01-02 to 2025-03-20
Data columns (total 4 columns):
#   Column  Non-Null Count  Dtype
---  -
0   Close   8870 non-null     float64
1   High    8870 non-null     float64
2   Low     8870 non-null     float64
3   Open    8870 non-null     float64
dtypes: float64(4)
memory usage: 346.5 KB
None
The first 5 rows are:
```

	Close	High	Low	Open
Date				
1990-01-02	17.24	17.24	17.24	17.24
1990-01-03	18.19	18.19	18.19	18.19
1990-01-04	19.22	19.22	19.22	19.22
1990-01-05	20.11	20.11	20.11	20.11
1990-01-08	20.26	20.26	20.26	20.26

The last 5 rows are:

	Close	High	Low	Open
Date				
2025-03-14	21.77	24.36	21.48	24.35
2025-03-17	20.51	22.95	20.32	22.89
2025-03-18	21.70	22.57	20.41	20.83
2025-03-19	19.90	22.10	19.42	21.84
2025-03-20	19.80	21.17	19.30	19.52

```
[14]: vix_stats = vix.describe()
vix_stats
```

```
[14]:
```

	Close	High	Low	Open
count	8870.00	8870.00	8870.00	8870.00
mean	19.46	20.37	18.80	19.56
std	7.82	8.36	7.39	7.90
min	9.14	9.31	8.56	9.01
25%	13.84	14.50	13.39	13.92
50%	17.62	18.32	17.03	17.66
75%	22.81	23.80	22.13	22.96
max	82.69	89.53	72.76	82.69

```
[15]: vix_stats.loc['mean + 1 std'] = {'Open': vix_stats.loc['mean']['Open'] +
    ↪vix_stats.loc['std']['Open'],
    'High': vix_stats.loc['mean']['High'] +
    ↪vix_stats.loc['std']['High'],
    'Low': vix_stats.loc['mean']['Low'] +
    ↪vix_stats.loc['std']['Low'],
    'Close': vix_stats.loc['mean']['Close'] +
    ↪vix_stats.loc['std']['Close']}
vix_stats.loc['mean + 2 std'] = {'Open': vix_stats.loc['mean']['Open'] + 2 *
    ↪vix_stats.loc['std']['Open'],
    'High': vix_stats.loc['mean']['High'] + 2 *
    ↪vix_stats.loc['std']['High'],
    'Low': vix_stats.loc['mean']['Low'] + 2 *
    ↪vix_stats.loc['std']['Low'],
    'Close': vix_stats.loc['mean']['Close'] + 2 *
    ↪vix_stats.loc['std']['Close']}
vix_stats.loc['mean - 1 std'] = {'Open': vix_stats.loc['mean']['Open'] -
    ↪vix_stats.loc['std']['Open'],
    'High': vix_stats.loc['mean']['High'] -
    ↪vix_stats.loc['std']['High'],
    'Low': vix_stats.loc['mean']['Low'] -
    ↪vix_stats.loc['std']['Low'],
    'Close': vix_stats.loc['mean']['Close'] -
    ↪vix_stats.loc['std']['Close']}
```

```
[16]: vix_stats
```

```
[16]:
```

	Close	High	Low	Open
count	8870.00	8870.00	8870.00	8870.00
mean	19.46	20.37	18.80	19.56
std	7.82	8.36	7.39	7.90
min	9.14	9.31	8.56	9.01
25%	13.84	14.50	13.39	13.92
50%	17.62	18.32	17.03	17.66
75%	22.81	23.80	22.13	22.96
max	82.69	89.53	72.76	82.69
mean + 1 std	27.29	28.73	26.19	27.45
mean + 2 std	35.11	37.09	33.58	35.35
mean - 1 std	11.64	12.00	11.40	11.66

```
[17]: deciles = vix.quantile(np.arange(0, 1.1, 0.1))
display(deciles)
```

	Close	High	Low	Open
0.00	9.14	9.31	8.56	9.01
0.10	12.11	12.62	11.72	12.13
0.20	13.24	13.86	12.84	13.29
0.30	14.57	15.27	14.06	14.64
0.40	16.07	16.74	15.53	16.11
0.50	17.62	18.32	17.03	17.66
0.60	19.53	20.36	18.98	19.65
0.70	21.59	22.60	20.96	21.74
0.80	24.28	25.29	23.45	24.37
0.90	28.67	29.95	27.74	28.82
1.00	82.69	89.53	72.76	82.69

```
[18]: # Plotting
plt.figure(figsize=(12, 6), facecolor="#F5F5F5")

# Histogram
plt.hist([vix['High']], label=['High'], bins=200, edgecolor='black',
        color='steelblue')

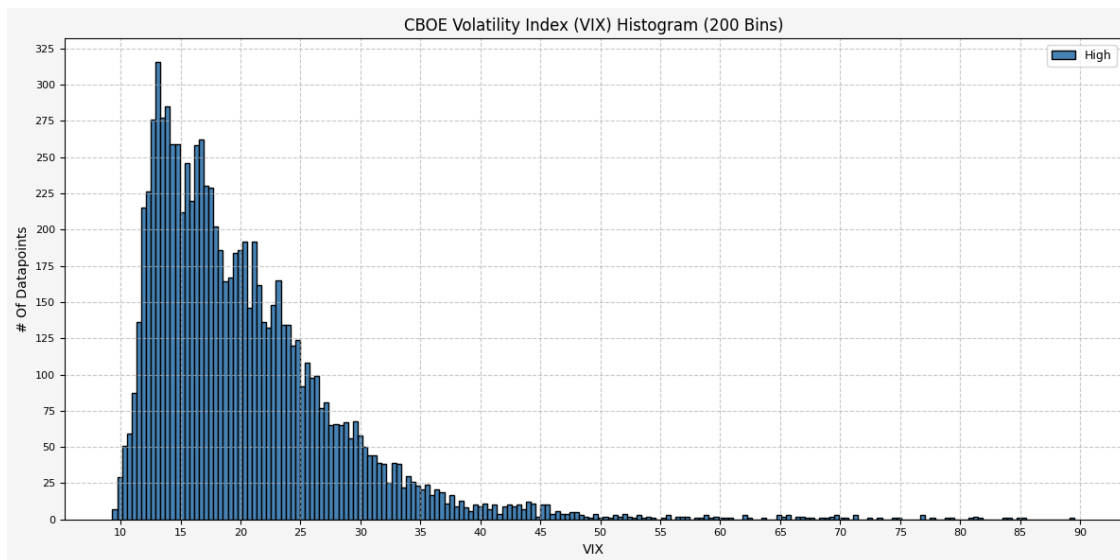
# Set X axis
x_tick_spacing = 5 # Specify the interval for y-axis ticks
plt.gca().xaxis.set_major_locator(MultipleLocator(x_tick_spacing))
plt.xlabel("VIX", fontsize=10)
plt.xticks(rotation=0, fontsize=8)

# Set Y axis
y_tick_spacing = 25 # Specify the interval for y-axis ticks
plt.gca().yaxis.set_major_locator(MultipleLocator(y_tick_spacing))
plt.ylabel("# Of Datapoints", fontsize=10)
```

```
plt.yticks(fontsize=8)

# Set title, layout, grid, and legend
plt.title("CBOE Volatility Index (VIX) Histogram (200 Bins)", fontsize=12)
plt.tight_layout()
plt.grid(True, linestyle='--', alpha=0.7)
plt.legend(fontsize=9)

# Save figure and display plot
plt.savefig("04_Histogram.png", dpi=300, bbox_inches="tight")
plt.show()
```



```
[19]: # Plotting
plt.figure(figsize=(12, 6), facecolor="#F5F5F5")

# Histogram
plt.hist([vix['High']], label=['High'], bins=200, edgecolor='black',
        color='steelblue')

# Plot a vertical line at the mean, mean + 1 std, and mean + 2 std
plt.axvline(vix_stats.loc['mean']['High'], color='red', linestyle='dashed',
            linewidth=1, label=f'Mean: {vix_stats.loc['mean']['High']:.2f}')
plt.axvline(vix_stats.loc['mean + 1 std']['High'], color='green',
            linestyle='dashed', linewidth=1, label=f'Mean + 1 std: {vix_stats.loc['mean + 1 std']['High']:.2f}')
plt.axvline(vix_stats.loc['mean + 2 std']['High'], color='orange',
            linestyle='dashed', linewidth=1, label=f'Mean + 2 std: {vix_stats.loc['mean + 2 std']['High']:.2f}')
```

```

plt.axvline(vix_stats.loc['mean - 1 std']['High'], color='brown',
            linestyle='dashed', linewidth=1, label=f'Mean - 1 std: {vix_stats.loc['mean - 1 std']['High']:.2f}')

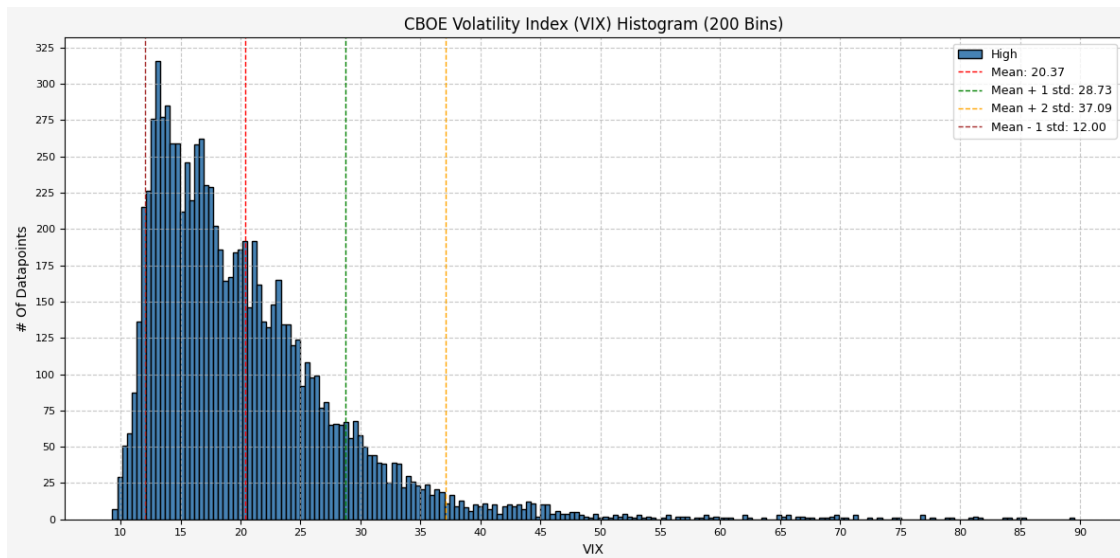
# Set X axis
x_tick_spacing = 5 # Specify the interval for y-axis ticks
plt.gca().axis.set_major_locator(MultipleLocator(x_tick_spacing))
plt.xlabel("VIX", fontsize=10)
plt.xticks(rotation=0, fontsize=8)

# Set Y axis
y_tick_spacing = 25 # Specify the interval for y-axis ticks
plt.gca().axis.set_major_locator(MultipleLocator(y_tick_spacing))
plt.ylabel("# Of Datapoints", fontsize=10)
plt.yticks(fontsize=8)

# Set title, layout, grid, and legend
plt.title("CBOE Volatility Index (VIX) Histogram (200 Bins)", fontsize=12)
plt.tight_layout()
plt.grid(True, linestyle='--', alpha=0.7)
plt.legend(fontsize=9)

# Save figure and display plot
plt.savefig("05_Histogram+Mean.png", dpi=300, bbox_inches="tight")
plt.show()

```



1.6 Plots

1.6.1 CBOE Volatility Index (VIX)

1990 - 2009

```
[20]: # Plotting
plt.figure(figsize=(12, 6), facecolor="#F5F5F5")

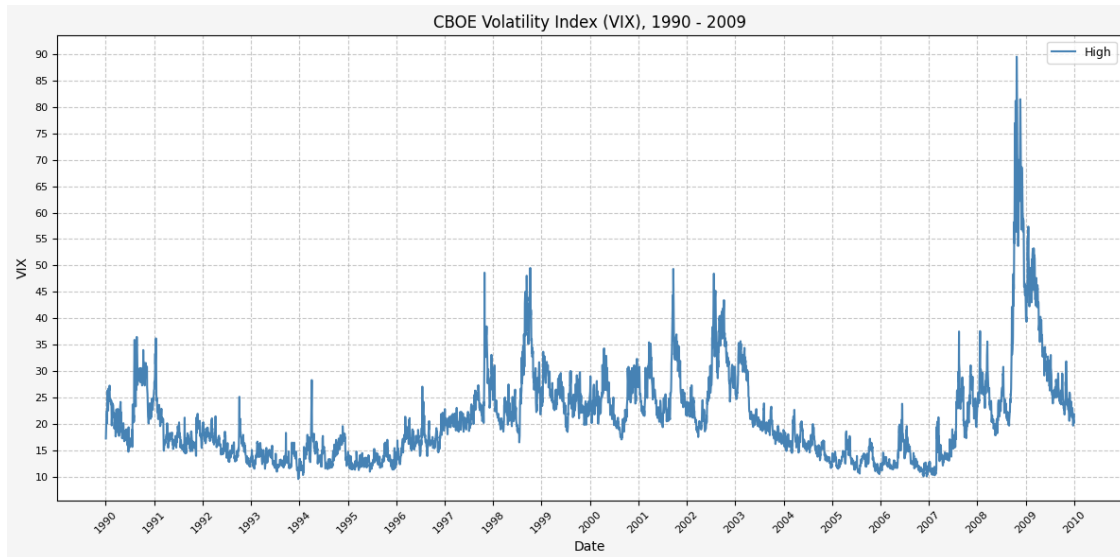
# Plot data
plt.plot(vix[vix.index <= '2009-12-31'].index, vix[vix.index <=
    ↪ '2009-12-31']['High'], label='High', linestyle='-', color='steelblue',
    ↪ linewidth=1.5)
# plt.plot(vix.index, vix['SMA_10'], label='10 Day SMA', linestyle='-',
    ↪ color='r', linewidth=1)
# plt.plot(vix.index, vix['SMA_20'], label='20 Day SMA', linestyle='-',
    ↪ color='orange', linewidth=1)
# plt.plot(vix.index, vix['SMA_50'], label='50 Day SMA', linestyle='-',
    ↪ color='g', linewidth=1)

# Set X axis
plt.gca().xaxis.set_major_locator(mdates.YearLocator())
plt.gca().xaxis.set_major_formatter(mdates.DateFormatter('%Y'))
plt.xlabel("Date", fontsize=10)
plt.xticks(rotation=45, fontsize=8)

# Set Y axis
y_tick_spacing = 5 # Specify the interval for y-axis ticks
plt.gca().yaxis.set_major_locator(MultipleLocator(y_tick_spacing))
plt.ylabel("VIX", fontsize=10)
plt.yticks(fontsize=8)

# Set title, layout, grid, and legend
plt.title("CBOE Volatility Index (VIX), 1990 - 2009", fontsize=12)
plt.tight_layout()
plt.grid(True, linestyle='--', alpha=0.7)
plt.legend(fontsize=9)

# Save figure and display plot
plt.savefig("06_Plot_1990-2009.png", dpi=300, bbox_inches="tight")
plt.show()
```



```
[21]: # Plotting
plt.figure(figsize=(12, 6), facecolor="#F5F5F5")

# Plot data
plt.plot(vix[vix.index > '2009-12-31'].index, vix[vix.index >
    ↪ '2009-12-31']['High'], label='High', linestyle='-', color='steelblue',
    ↪ linewidth=1.5)
# plt.plot(vix.index, vix['SMA_10'], label='10 Day SMA', linestyle='-',
    ↪ color='r', linewidth=1)
# plt.plot(vix.index, vix['SMA_20'], label='20 Day SMA', linestyle='-',
    ↪ color='orange', linewidth=1)
# plt.plot(vix.index, vix['SMA_50'], label='50 Day SMA', linestyle='-',
    ↪ color='g', linewidth=1)

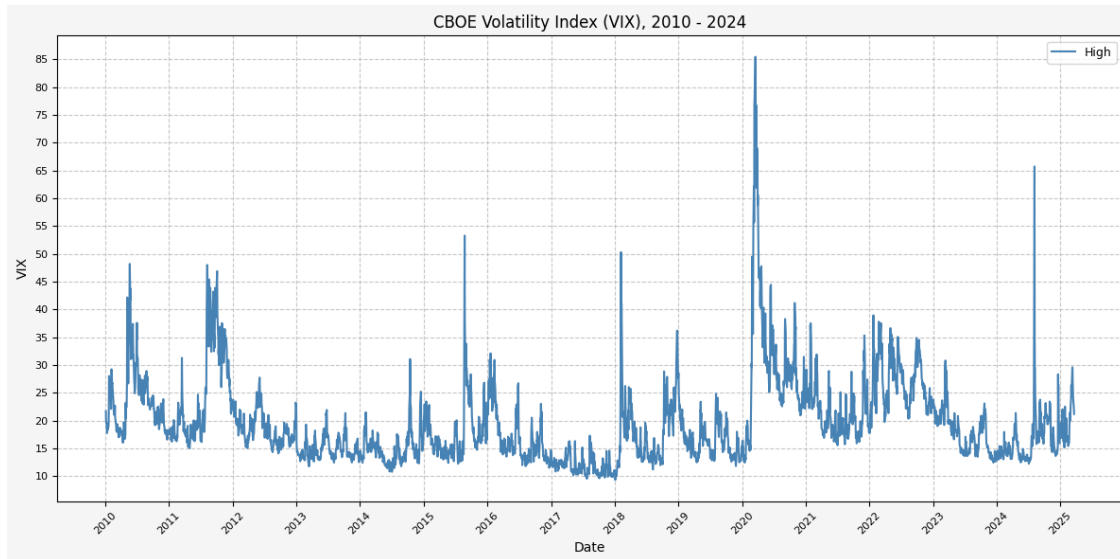
# Set X axis
plt.gca().xaxis.set_major_locator(mdates.YearLocator())
plt.gca().xaxis.set_major_formatter(mdates.DateFormatter('%Y'))
plt.xlabel("Date", fontsize=10)
plt.xticks(rotation=45, fontsize=8)

# Set Y axis
y_tick_spacing = 5 # Specify the interval for y-axis ticks
plt.gca().yaxis.set_major_locator(MultipleLocator(y_tick_spacing))
plt.ylabel("VIX", fontsize=10)
plt.yticks(fontsize=8)

# Set title, layout, grid, and legend
plt.title("CBOE Volatility Index (VIX), 2010 - 2024", fontsize=12)
```

```
plt.tight_layout()
plt.grid(True, linestyle='--', alpha=0.7)
plt.legend(fontsize=9)

# Save figure and display plot
plt.savefig("07_Plot_2010-2024.png", dpi=300, bbox_inches="tight")
plt.show()
```



1.7 Determining A Spike Level

```
[22]: # Define the spike multiplier for detecting significant spikes
spike_level = 1.25

# =====
# Simple Moving Averages (SMA)
# =====

# Calculate 10-period SMA of 'High'
vix['High_SMA_10'] = vix['High'].rolling(window=10).mean()

# Shift the 10-period SMA by 1 to compare with current 'High'
vix['High_SMA_10_Shift'] = vix['High_SMA_10'].shift(1)

# Calculate the spike level based on shifted SMA and spike multiplier
vix['Spike_Level_SMA'] = vix['High_SMA_10_Shift'] * spike_level

# Calculate 20-period SMA of 'High'
vix['High_SMA_20'] = vix['High'].rolling(window=20).mean()
```

```

# Determine if 'High' exceeds the spike level (indicates a spike)
vix['Spike_SMA'] = vix['High'] >= vix['Spike_Level_SMA']

# Calculate 50-period SMA of 'High' for trend analysis
vix['High_SMA_50'] = vix['High'].rolling(window=50).mean()

# =====
# Exponential Moving Averages (EMA)
# =====

# Calculate 10-period EMA of 'High'
vix['High_EMA_10'] = vix['High'].ewm(span=10, adjust=False).mean()

# Shift the 10-period EMA by 1 to compare with current 'High'
vix['High_EMA_10_Shift'] = vix['High_EMA_10'].shift(1)

# Calculate the spike level based on shifted EMA and spike multiplier
vix['Spike_Level_EMA'] = vix['High_EMA_10_Shift'] * spike_level

# Calculate 20-period EMA of 'High'
vix['High_EMA_20'] = vix['High'].ewm(span=20, adjust=False).mean()

# Determine if 'High' exceeds the spike level (indicates a spike)
vix['Spike_EMA'] = vix['High'] >= vix['Spike_Level_EMA']

# Calculate 50-period EMA of 'High' for trend analysis
vix['High_EMA_50'] = vix['High'].ewm(span=50, adjust=False).mean()

```

```
[23]: vix.head()
```

```

[23]:
      Close  High  Low  Open  High_SMA_10  High_SMA_10_Shift  \
Date
1990-01-02  17.24  17.24  17.24  17.24          NaN          NaN
1990-01-03  18.19  18.19  18.19  18.19          NaN          NaN
1990-01-04  19.22  19.22  19.22  19.22          NaN          NaN
1990-01-05  20.11  20.11  20.11  20.11          NaN          NaN
1990-01-08  20.26  20.26  20.26  20.26          NaN          NaN

      Spike_Level_SMA  High_SMA_20  Spike_SMA  High_SMA_50  High_EMA_10  \
Date
1990-01-02          NaN          NaN      False          NaN          17.24
1990-01-03          NaN          NaN      False          NaN          17.41
1990-01-04          NaN          NaN      False          NaN          17.74
1990-01-05          NaN          NaN      False          NaN          18.17
1990-01-08          NaN          NaN      False          NaN          18.55

```

	High_EMA_10_Shift	Spike_Level_EMA	High_EMA_20	Spike_EMA	\
Date					
1990-01-02	NaN	NaN	17.24	False	
1990-01-03	17.24	21.55	17.33	False	
1990-01-04	17.41	21.77	17.51	False	
1990-01-05	17.74	22.18	17.76	False	
1990-01-08	18.17	22.71	18.00	False	

	High_EMA_50
Date	
1990-01-02	17.24
1990-01-03	17.28
1990-01-04	17.35
1990-01-05	17.46
1990-01-08	17.57

[24]: vix.tail()

	Close	High	Low	Open	High_SMA_10	High_SMA_10_Shift	\
Date							
2025-03-14	21.77	24.36	21.48	24.35	26.45	26.25	
2025-03-17	20.51	22.95	20.32	22.89	26.31	26.45	
2025-03-18	21.70	22.57	20.41	20.83	25.94	26.31	
2025-03-19	19.90	22.10	19.42	21.84	25.66	25.94	
2025-03-20	19.80	21.17	19.30	19.52	25.19	25.66	

	Spike_Level_SMA	High_SMA_20	Spike_SMA	High_SMA_50	High_EMA_10	\
Date						
2025-03-14	32.82	22.66	False	19.78	25.58	
2025-03-17	33.06	23.04	False	19.88	25.10	
2025-03-18	32.89	23.36	False	19.94	24.64	
2025-03-19	32.42	23.67	False	20.03	24.18	
2025-03-20	32.08	23.90	False	20.11	23.63	

	High_EMA_10_Shift	Spike_Level_EMA	High_EMA_20	Spike_EMA	\
Date					
2025-03-14	25.85	32.31	23.67	False	
2025-03-17	25.58	31.97	23.60	False	
2025-03-18	25.10	31.37	23.50	False	
2025-03-19	24.64	30.80	23.37	False	
2025-03-20	24.18	30.22	23.16	False	

	High_EMA_50
Date	
2025-03-14	20.92
2025-03-17	21.00
2025-03-18	21.06

```

2025-03-19      21.11
2025-03-20      21.11

```

```
[25]: vix[vix['High'] >= 50]
```

```

[25]:
      Close  High   Low  Open  High_SMA_10  High_SMA_10_Shift  \
Date
2008-10-06  52.05  58.24  45.12  45.12          42.92          40.52
2008-10-07  53.68  54.19  47.03  52.05          44.73          42.92
2008-10-08  57.53  59.06  51.90  53.68          46.97          44.73
2008-10-09  63.92  64.92  52.54  57.57          49.94          46.97
2008-10-10  69.95  76.94  65.63  65.85          53.99          49.94
...
2020-03-31  53.54  58.75  50.88  56.69          70.93          73.54
2020-04-01  57.06  60.59  52.76  57.38          68.44          70.93
2020-04-02  50.91  57.24  50.45  54.46          65.74          68.44
2020-04-03  46.80  52.29  46.74  51.11          64.02          65.74
2024-08-05  38.57  65.73  23.39  23.39          23.84          18.95

      Spike_Level_SMA  High_SMA_20  Spike_SMA  High_SMA_50  High_EMA_10  \
Date
2008-10-06          50.65        37.24      True        28.17        44.33
2008-10-07          53.65        38.66      True        28.76        46.12
2008-10-08          55.91        40.34      True        29.46        48.47
2008-10-09          58.71        42.27      True        30.31        51.46
2008-10-10          62.42        44.79      True        31.39        56.10
...
2020-03-31          91.93        66.93     False        39.38        67.38
2020-04-01          88.67        68.18     False        40.33        66.15
2020-04-02          85.56        68.90     False        41.21        64.53
2020-04-03          82.18        68.79     False        41.98        62.30
2024-08-05          23.69        19.11      True        15.66        28.04

      High_EMA_10_Shift  Spike_Level_EMA  High_EMA_20  Spike_EMA  \
Date
2008-10-06          41.24          51.55        38.82      True
2008-10-07          44.33          55.41        40.29     False
2008-10-08          46.12          57.65        42.07      True
2008-10-09          48.47          60.59        44.25      True
2008-10-10          51.46          64.33        47.36      True
...
2020-03-31          69.30          86.62        63.00     False
2020-04-01          67.38          84.23        62.77     False
2020-04-02          66.15          82.68        62.24     False
2020-04-03          64.53          80.66        61.30     False
2024-08-05          19.66          24.58        22.15      True

```

Date	High_EMA_50
2008-10-06	31.65
2008-10-07	32.53
2008-10-08	33.57
2008-10-09	34.80
2008-10-10	36.46
...	...
2020-03-31	46.75
2020-04-01	47.29
2020-04-02	47.68
2020-04-03	47.86
2024-08-05	17.62

[93 rows x 16 columns]

1.7.1 Spike Totals By Year

```
[26]: # Ensure the index is a DatetimeIndex
vix.index = pd.to_datetime(vix.index)

# Create a new column for the year extracted from the date index
vix['Year'] = vix.index.year

# Group by year and the "Spike_SMA" and "Spike_EMA" columns, then count
↳ occurrences
spike_count_SMA = vix.groupby(['Year', 'Spike_SMA']).size().
↳ unstack(fill_value=0)

spike_count_SMA
```

```
[26]: Spike_SMA  False  True
Year
1990           248      5
1991           249      4
1992           250      4
1993           251      2
1994           243      9
1995           252      0
1996           248      6
1997           247      6
1998           243      9
1999           250      2
2000           248      4
2001           240      8
2002           248      4
2003           251      1
```

2004	250	2
2005	250	2
2006	242	9
2007	239	12
2008	238	15
2009	249	3
2010	239	13
2011	240	12
2012	248	2
2013	249	3
2014	235	17
2015	240	12
2016	234	18
2017	244	7
2018	228	23
2019	241	11
2020	224	29
2021	235	17
2022	239	12
2023	246	4
2024	237	15
2025	48	5

```
[27]: # Ensure the index is a DatetimeIndex
vix.index = pd.to_datetime(vix.index)

# Create a new column for the year extracted from the date index
vix['Year'] = vix.index.year

# Group by year and the "Spike_SMA" and "Spike_EMA" columns, then count_
↳ occurrences
spike_count_EMA = vix.groupby(['Year', 'Spike_EMA']).size().
↳ unstack(fill_value=0)

spike_count_EMA
```

```
[27]: Spike_EMA  False  True
Year
1990           247     6
1991           251     2
1992           253     1
1993           251     2
1994           247     5
1995           252     0
1996           252     2
1997           250     3
1998           246     6
```


1999	250	2
2000	250	2
2001	241	7
2002	250	2
2003	251	1
2004	251	1
2005	250	2
2006	248	3
2007	242	9
2008	240	13
2009	251	1
2010	243	9
2011	242	10
2012	250	0
2013	250	2
2014	236	16
2015	243	9
2016	238	14
2017	244	7
2018	230	21
2019	242	10
2020	228	25
2021	239	13
2022	244	7
2023	248	2
2024	244	8
2025	50	3

```
[28]: # Plotting
plt.figure(figsize=(12, 6), facecolor="#F5F5F5")

# Bar positions
x = np.arange(len(spike_count_SMA[True].index))
width = 0.35

# Plot SMA bars
plt.bar(x - width / 2, spike_count_SMA[True].values, width, color="steelblue",
        label="Spike Counts Using SMA")

# Plot EMA bars
plt.bar(x + width / 2, spike_count_EMA[True].values, width,
        color="forestgreen", label="Spike Counts Using EMA")

# Set X axis
# x_tick_spacing = 5 # Specify the interval for y-axis ticks
# plt.gca().xaxis.set_major_locator(MultipleLocator(x_tick_spacing))
plt.xlabel("Year", fontsize=10)
```

```

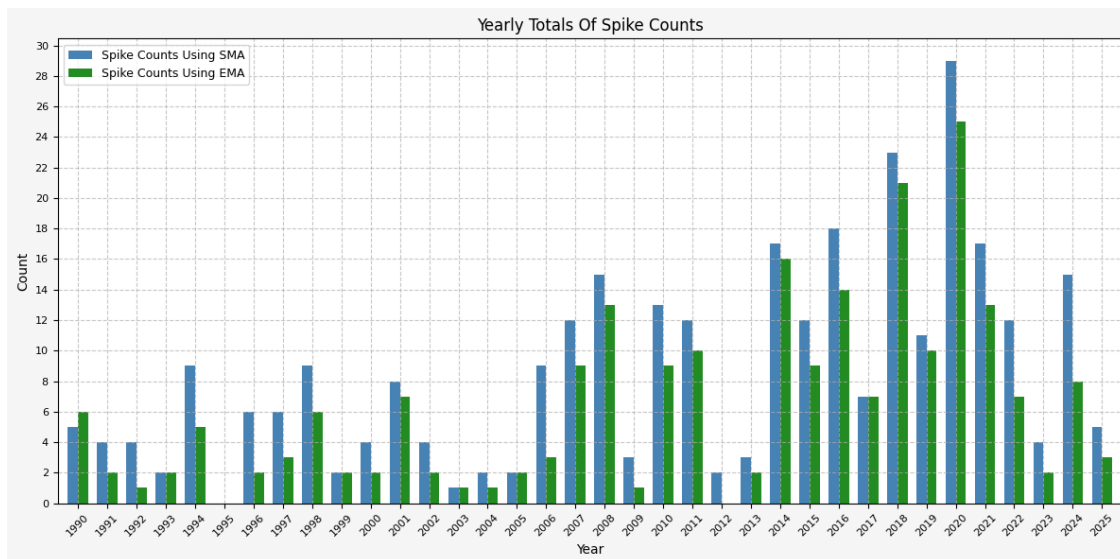
plt.xticks(x, spike_count_SMA[True].index, rotation=45, fontsize=8)
plt.xlim(x[0] - 2 * width, x[-1] + 2 * width)

# # Set Y axis
y_tick_spacing = 2 # Specify the interval for y-axis ticks
plt.gca().yaxis.set_major_locator(MultipleLocator(y_tick_spacing))
plt.ylabel("Count", fontsize=10)
plt.yticks(fontsize=8)

# Set title, layout, grid, and legend
plt.title("Yearly Totals Of Spike Counts", fontsize=12)
plt.tight_layout()
plt.grid(True, linestyle='--', alpha=0.7)
plt.legend(fontsize=9)

# Save figure and display plot
plt.savefig("08_Spike_Counts.png", dpi=300, bbox_inches="tight")
plt.show()

```



```

[29]: def vix_plot(start_year, end_year):
    # Start and end dates
    start_date = start_year + '-01-01'
    end_date = end_year + '-12-31'

    # Create temporary dataframe for the specified date range
    vix_temp = vix[(vix.index >= start_date) & (vix.index <= end_date)]

    # Plotting

```

```

plt.figure(figsize=(12, 6), facecolor="#F5F5F5")

# Plot data
plt.plot(vix_temp.index, vix_temp['High'], label='High', linestyle='-',
↪color='steelblue', linewidth=1)
plt.plot(vix_temp.index, vix_temp['Low'], label='Low', linestyle='-',
↪color='brown', linewidth=1)
plt.plot(vix_temp.index, vix_temp['High_SMA_10'], label='10 Day High SMA',
↪linestyle='-', color='red', linewidth=1)
plt.plot(vix_temp.index, vix_temp['High_SMA_20'], label='20 Day High SMA',
↪linestyle='-', color='orange', linewidth=1)
plt.plot(vix_temp.index, vix_temp['High_SMA_50'], label='50 Day High SMA',
↪linestyle='-', color='green', linewidth=1)
plt.scatter(vix_temp[vix_temp['Spike_SMA'] == True].index,
↪vix_temp[vix_temp['Spike_SMA'] == True]['High'], label='Spike (High > 1.25 *
↪10 Day High SMA)', linestyle='-', color='black', s=20)

# Set X axis
plt.gca().xaxis.set_major_locator(mdates.MonthLocator())
plt.gca().xaxis.set_major_formatter(mdates.DateFormatter('%b %Y'))
plt.xlabel("Date", fontsize=10)
plt.xticks(rotation=45, fontsize=8)

# Set Y axis
y_tick_spacing = 5 # Specify the interval for y-axis ticks
plt.gca().yaxis.set_major_locator(MultipleLocator(y_tick_spacing))
plt.ylabel("VIX", fontsize=10)
plt.yticks(fontsize=8)

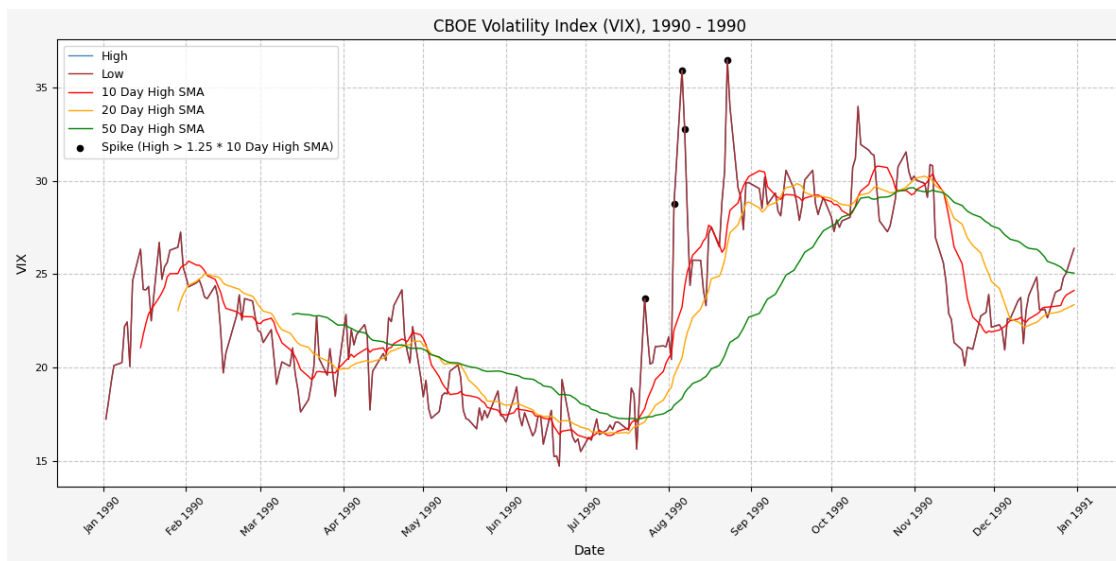
# Set title, layout, grid, and legend
plt.title(f"CBOE Volatility Index (VIX), {start_year} - {end_year}",
↪fontsize=12)
plt.tight_layout()
plt.grid(True, linestyle='--', alpha=0.7)
plt.legend(fontsize=9)

# Save figure and display plot
plt.savefig(f"09_VIX_SMA_Spike_{start_year}_{end_year}.png", dpi=300,
↪bbox_inches="tight")
plt.show()

```

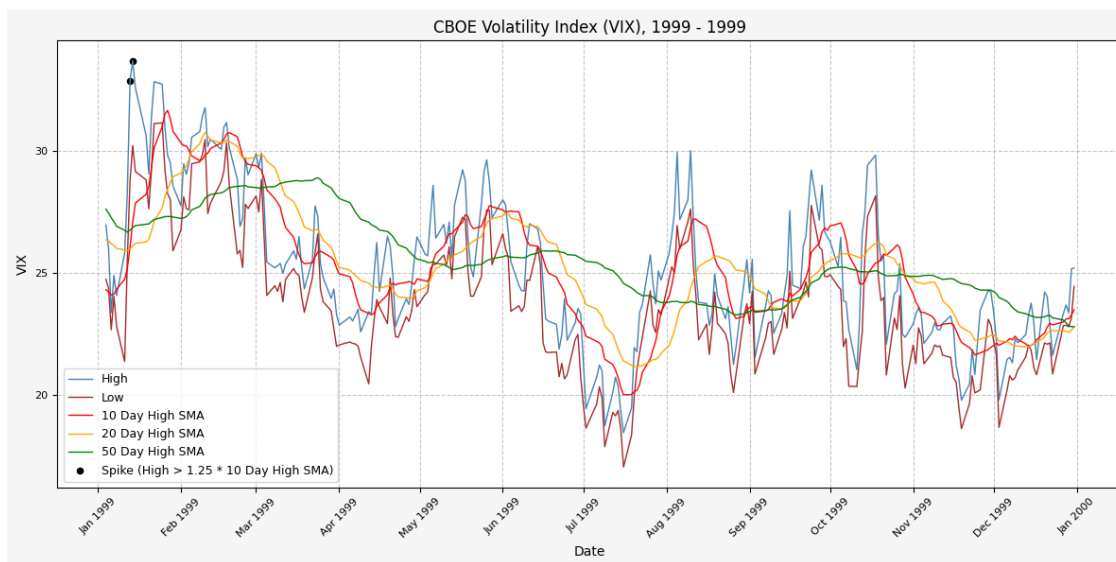
1990

[30]: vix_plot('1990', '1990')



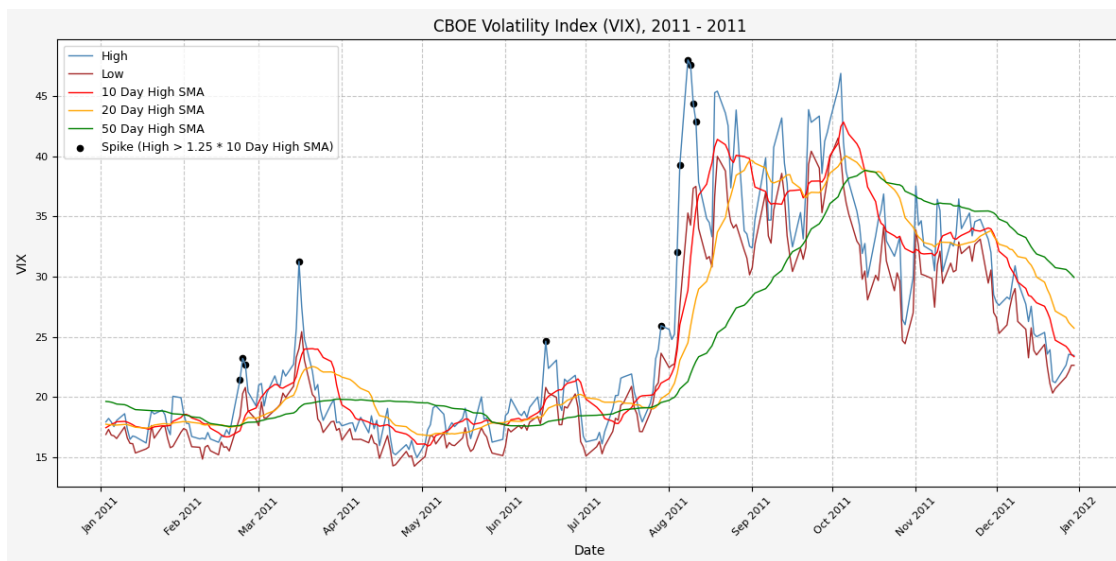
1999

```
[31]: vix_plot('1999', '1999')
```



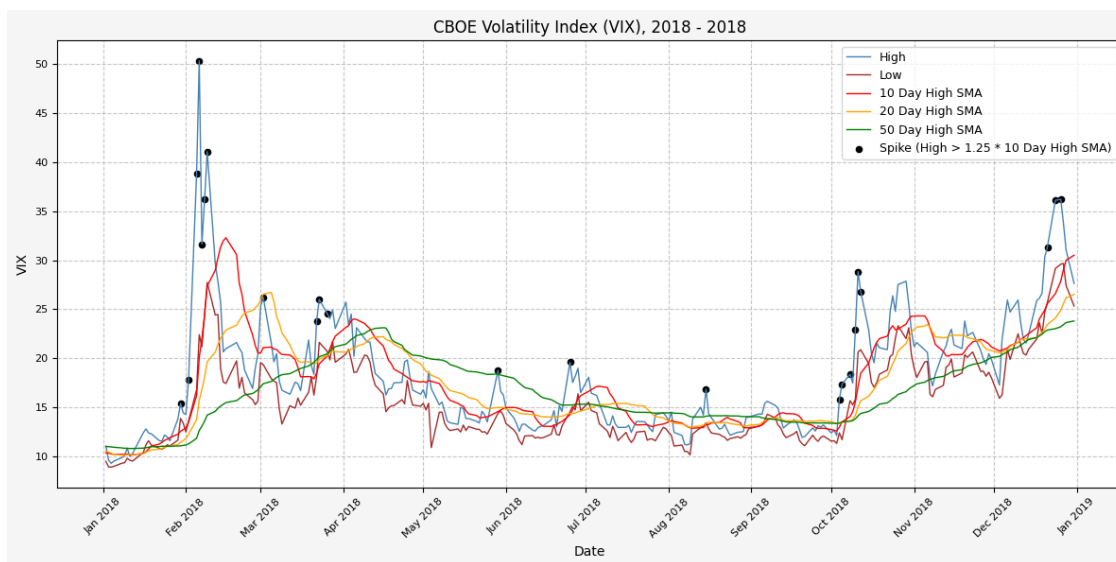
2011

```
[32]: vix_plot('2011', '2011')
```



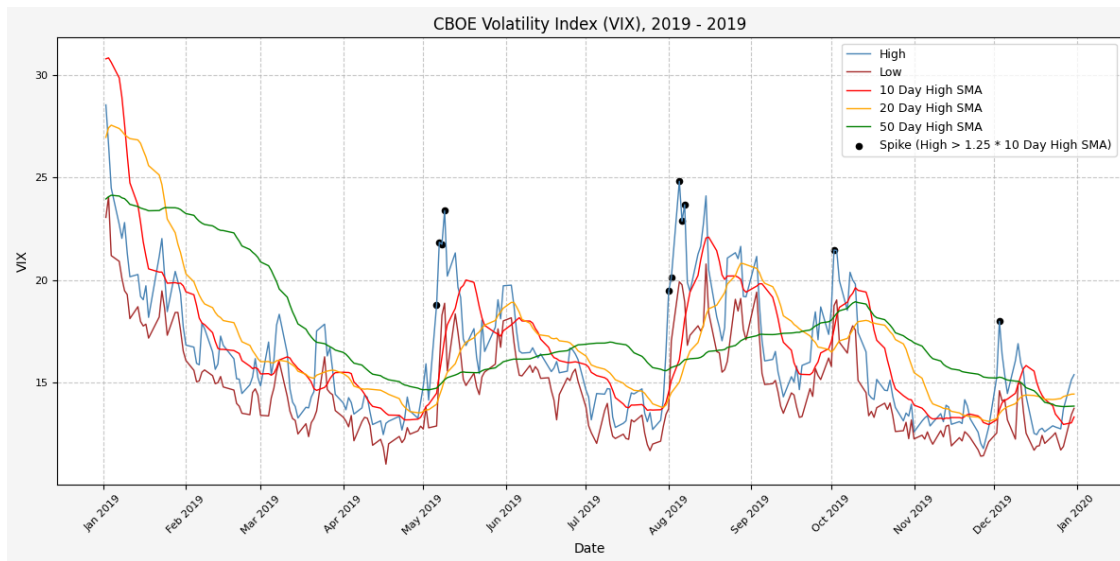
2018

```
[33]: vix_plot('2018', '2018')
```



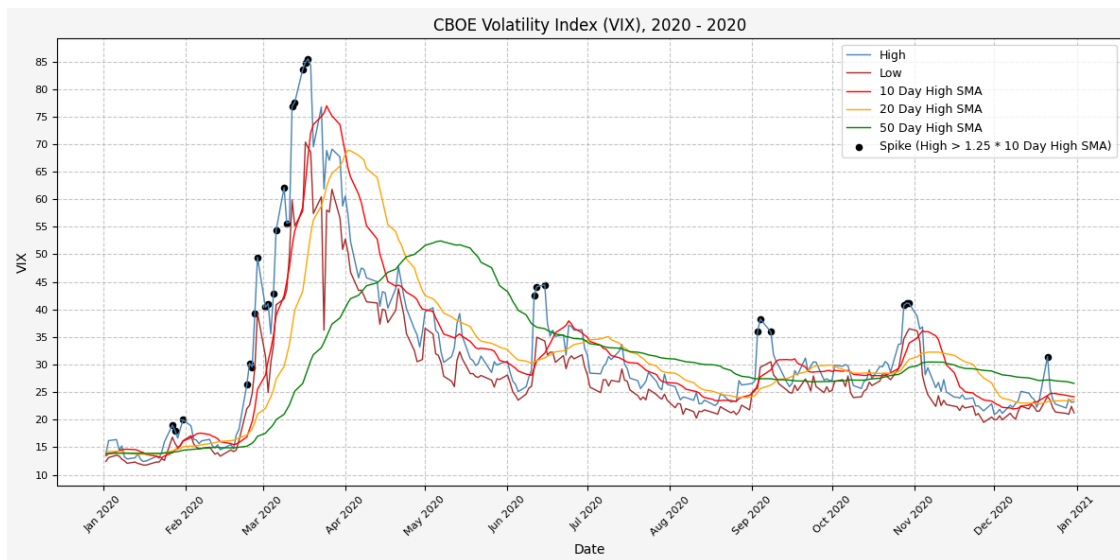
2019

```
[34]: vix_plot('2019', '2019')
```



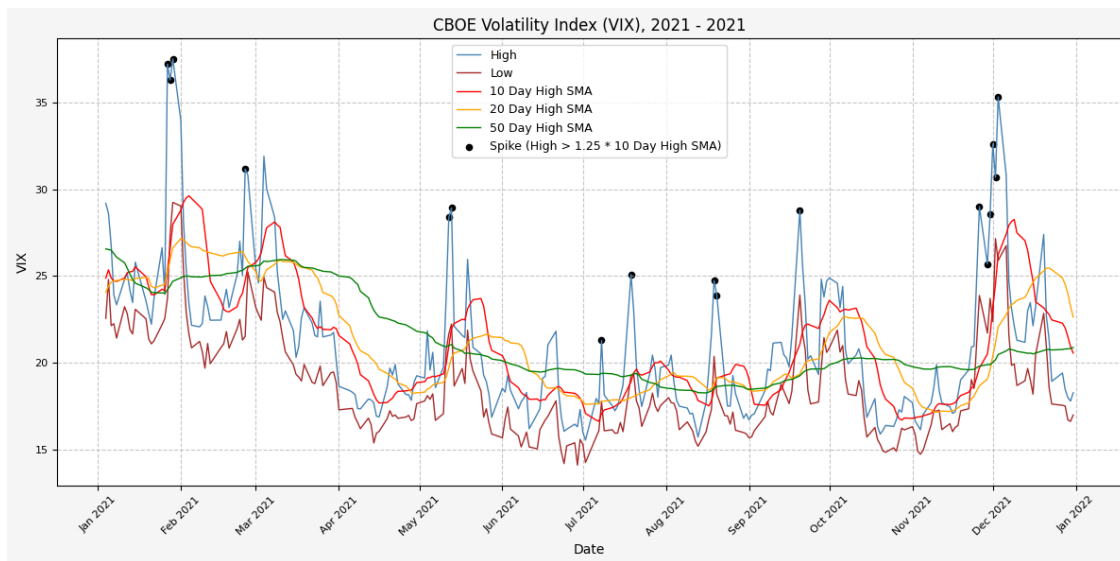
2020

```
[35]: vix_plot('2020', '2020')
```



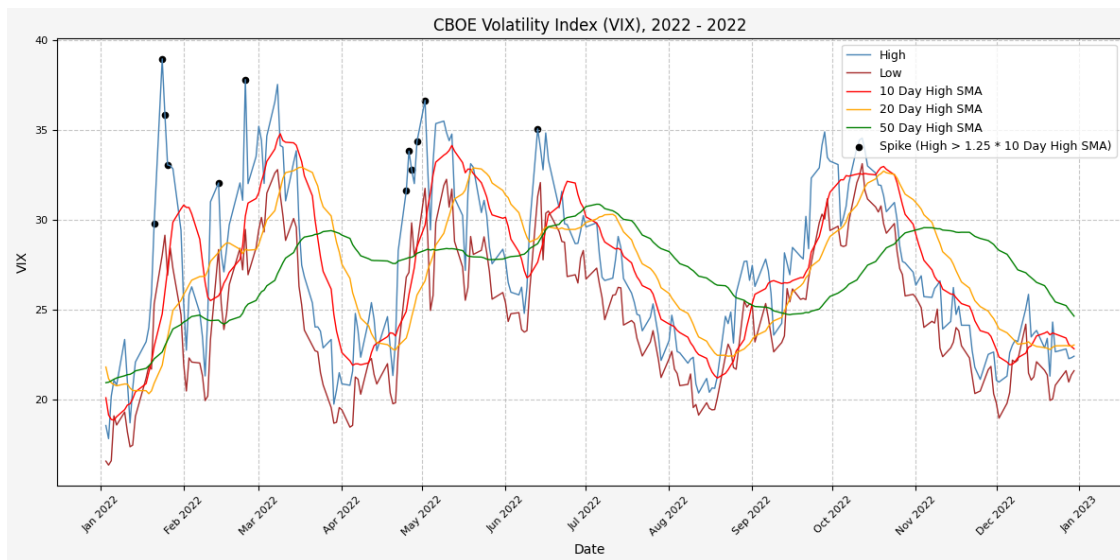
2021

```
[36]: vix_plot('2021', '2021')
```



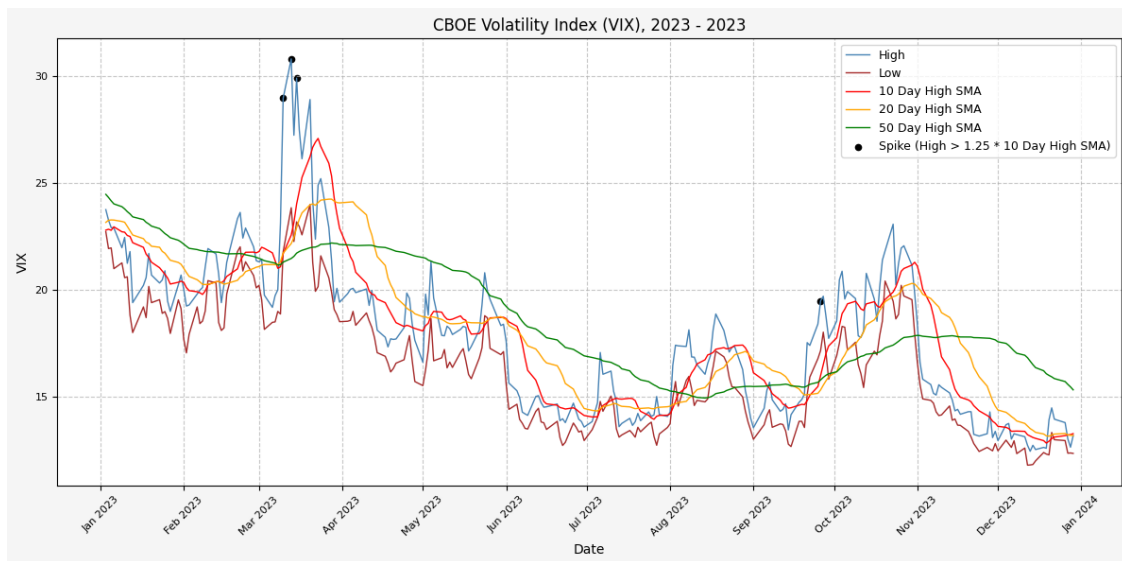
2022

```
[37]: vix_plot('2022', '2022')
```



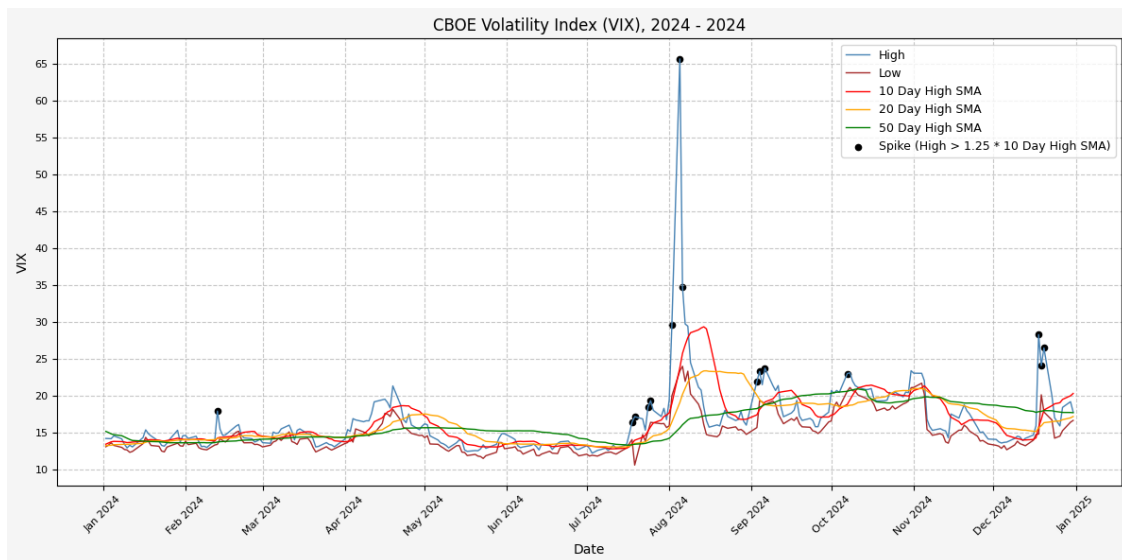
2023

```
[38]: vix_plot('2023', '2023')
```



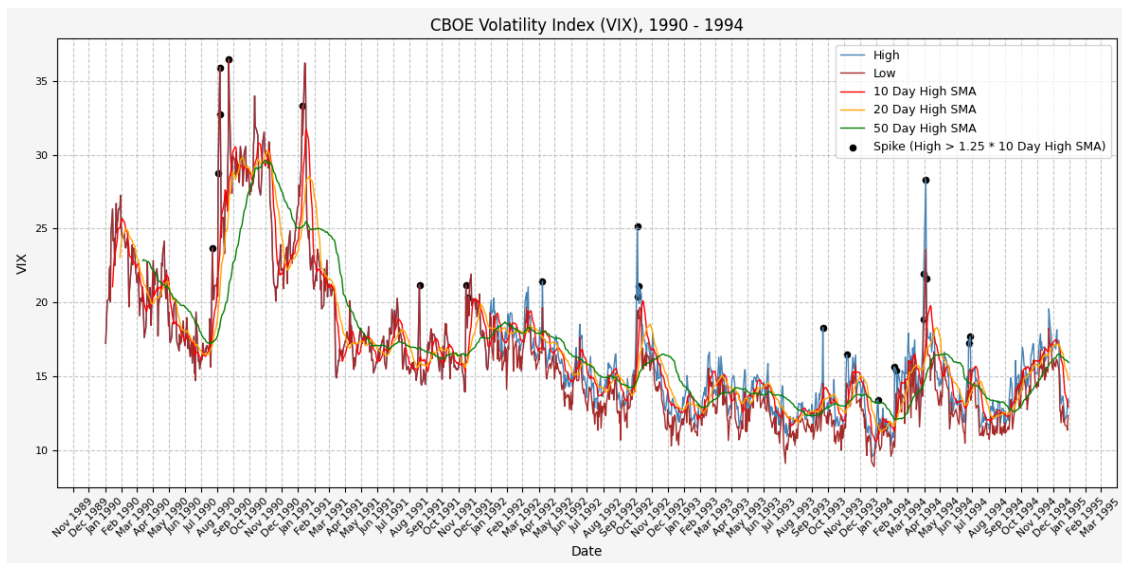
2024

```
[39]: vix_plot('2024', '2024')
```



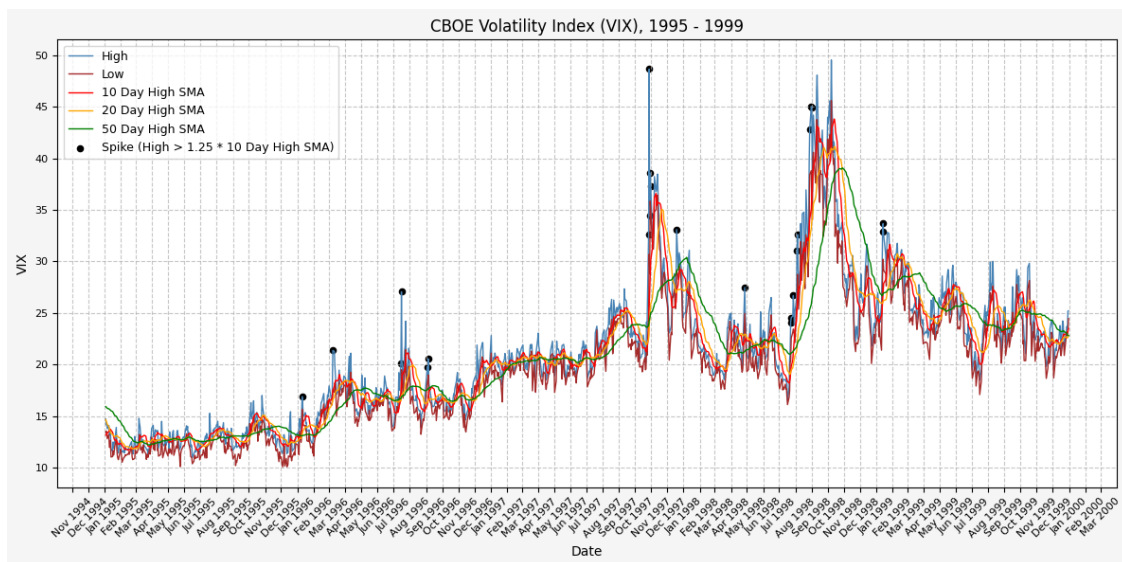
1990 - 1994

```
[40]: vix_plot('1990', '1994')
```

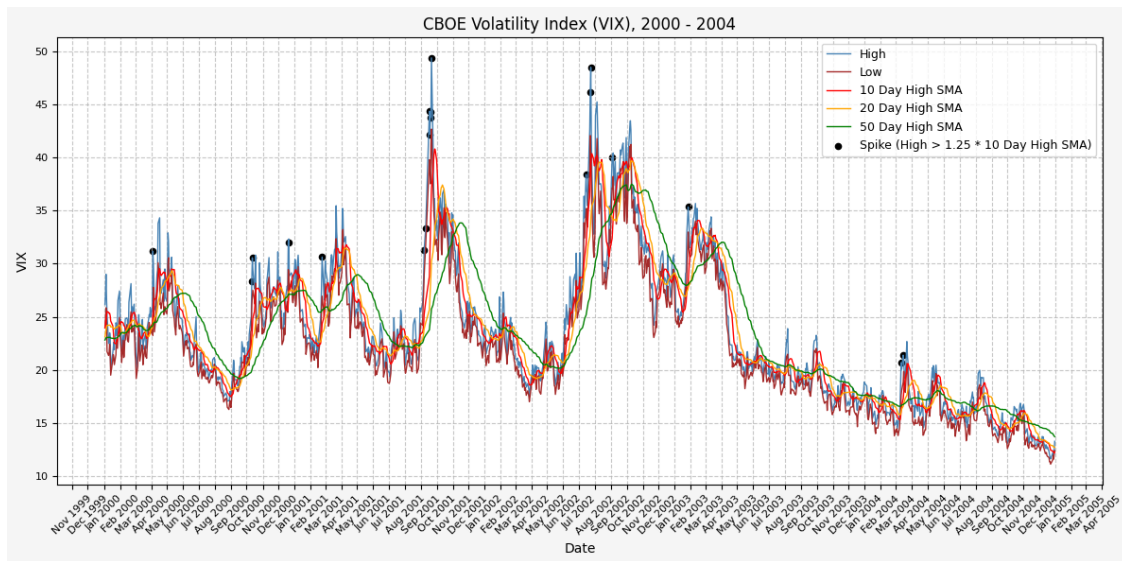
1995 - 1999

```
[41]: vix_plot('1995', '1999')
```



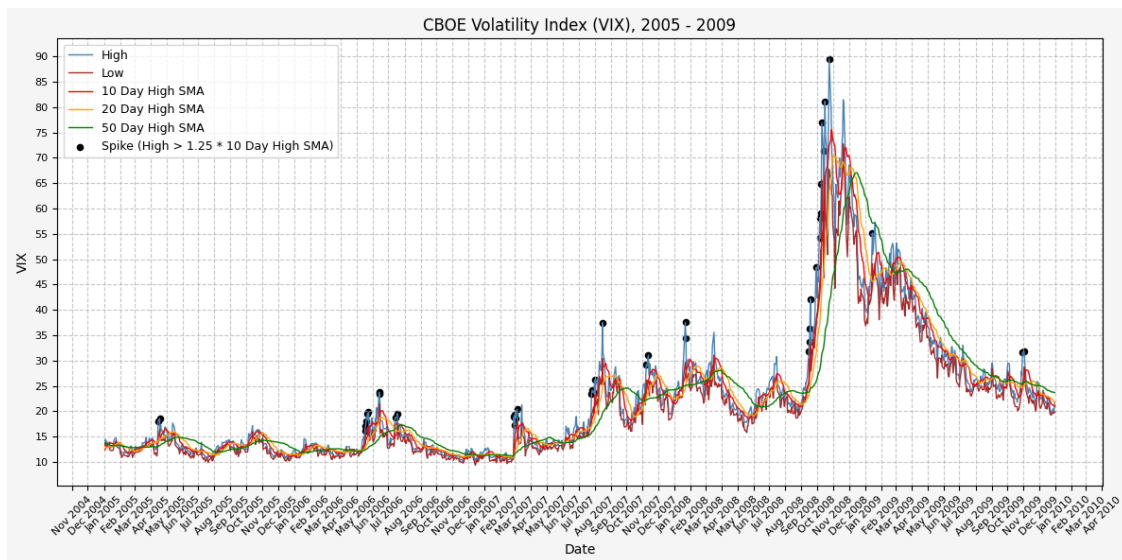
2000 - 2004

```
[42]: vix_plot('2000', '2004')
```



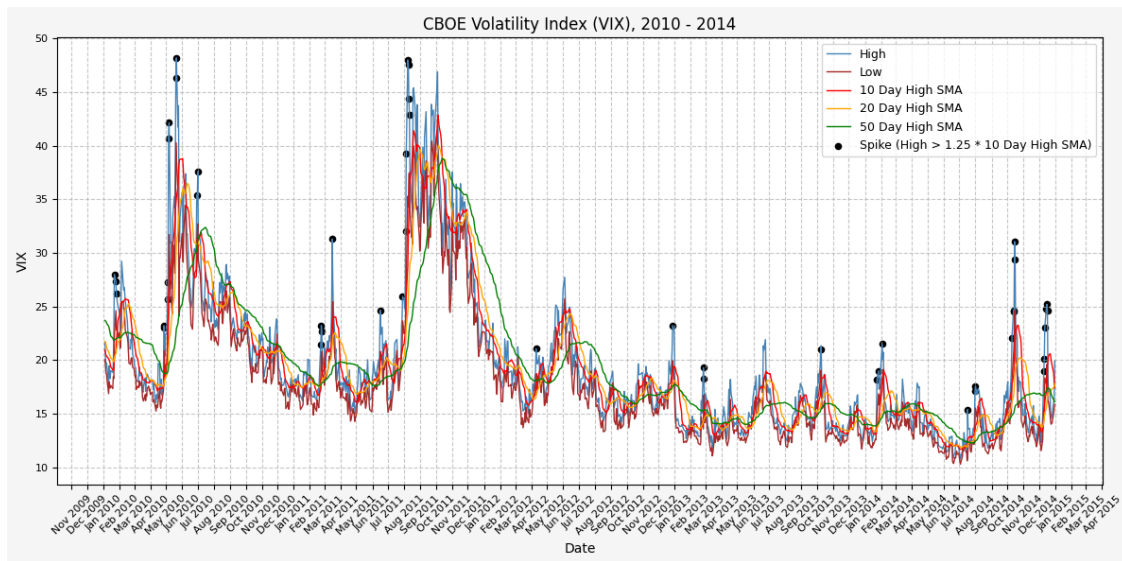
2005 - 2009

```
[43]: vix_plot('2005', '2009')
```



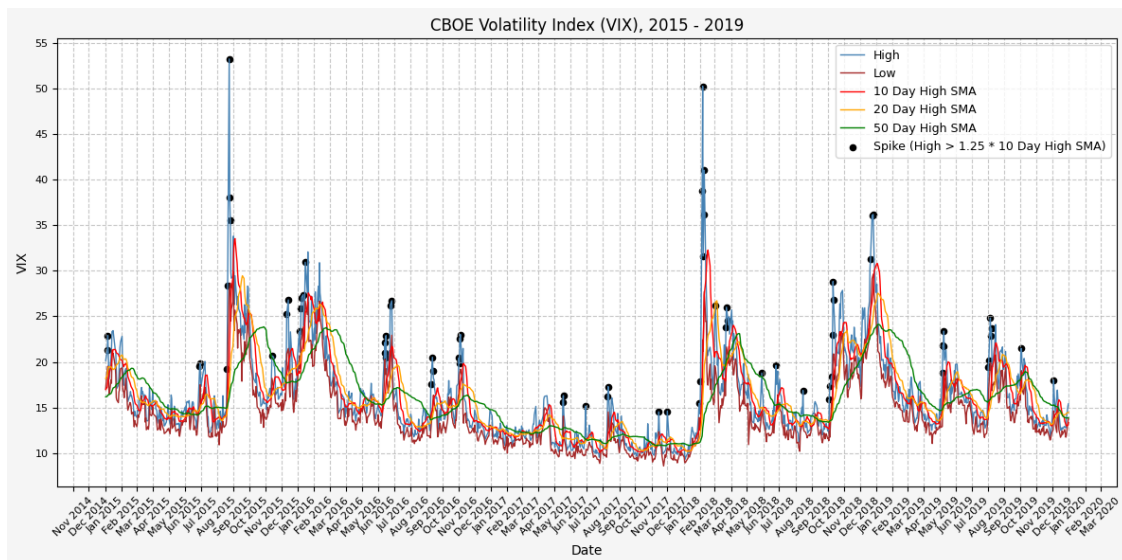
2010 - 2014

```
[44]: vix_plot('2010', '2014')
```



2015 - 2019

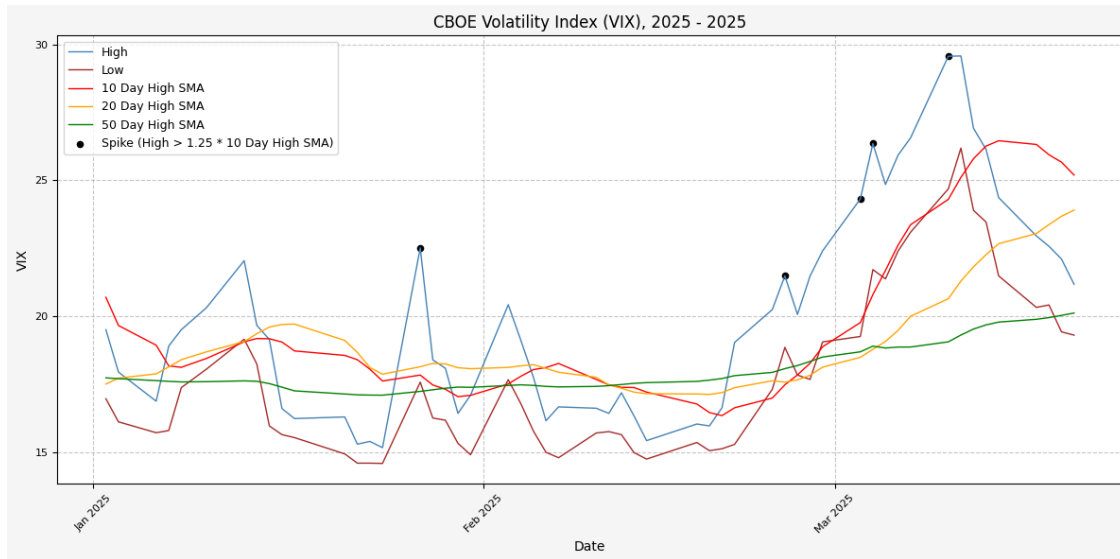
[45]: `vix_plot('2015', '2019')`



2020 - 2024

2025 - 2025

[47]: `vix_plot('2025', '2025')`



```
[48]: vix.tail(10)
```

```
[48]:
```

	Close	High	Low	Open	High_SMA_10	High_SMA_10_Shift \
Date						
2025-03-07	23.37	26.56	23.09	24.85	23.36	22.61
2025-03-10	27.86	29.56	24.68	24.70	24.29	23.36
2025-03-11	26.92	29.57	26.18	27.94	25.10	24.29
2025-03-12	24.23	26.91	23.89	26.88	25.79	25.10
2025-03-13	24.66	26.13	23.46	24.92	26.25	25.79
2025-03-14	21.77	24.36	21.48	24.35	26.45	26.25
2025-03-17	20.51	22.95	20.32	22.89	26.31	26.45
2025-03-18	21.70	22.57	20.41	20.83	25.94	26.31
2025-03-19	19.90	22.10	19.42	21.84	25.66	25.94
2025-03-20	19.80	21.17	19.30	19.52	25.19	25.66

	Spike_Level_SMA	High_SMA_20	Spike_SMA	High_SMA_50	High_EMA_10 \
Date					
2025-03-07	28.26	19.99	False	18.86	23.54
2025-03-10	29.20	20.64	True	19.05	24.64
2025-03-11	30.37	21.29	False	19.30	25.54
2025-03-12	31.38	21.81	False	19.52	25.79
2025-03-13	32.24	22.26	False	19.68	25.85
2025-03-14	32.82	22.66	False	19.78	25.58
2025-03-17	33.06	23.04	False	19.88	25.10
2025-03-18	32.89	23.36	False	19.94	24.64
2025-03-19	32.42	23.67	False	20.03	24.18
2025-03-20	32.08	23.90	False	20.11	23.63

	High_EMA_10_Shift	Spike_Level_EMA	High_EMA_20	Spike_EMA	\
Date					
2025-03-07	22.87	28.59	21.48	False	
2025-03-10	23.54	29.43	22.25	True	
2025-03-11	24.64	30.80	22.95	False	
2025-03-12	25.54	31.92	23.33	False	
2025-03-13	25.79	32.23	23.59	False	
2025-03-14	25.85	32.31	23.67	False	
2025-03-17	25.58	31.97	23.60	False	
2025-03-18	25.10	31.37	23.50	False	
2025-03-19	24.64	30.80	23.37	False	
2025-03-20	24.18	30.22	23.16	False	

	High_EMA_50	Year
Date		
2025-03-07	19.53	2025
2025-03-10	19.93	2025
2025-03-11	20.31	2025
2025-03-12	20.56	2025
2025-03-13	20.78	2025
2025-03-14	20.92	2025
2025-03-17	21.00	2025
2025-03-18	21.06	2025
2025-03-19	21.11	2025
2025-03-20	21.11	2025

[]: