investigating-a-vix-trading-signal-part-2-finding-a-signal

January 27, 2026

1 Investigating A VIX Trading Signal

1.1 Python Imports

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

from datetime import datetime, timedelta
from pathlib import Path

# Data Handling
import numpy as np
import pandas as pd

# Data Visualization
import matplotlib.dates as mdates
import matplotlib.pyplot as plt
import matplotlib.ticker as mtick
import seaborn as sns
from matplotlib.ticker import FormatStrFormatter, FuncFormatter, MultipleLocator

# Data Sources
import yfinance as yf

# Statistical Analysis
import statsmodels.api as sm

# Machine Learning
from sklearn.decomposition import PCA
from sklearn.preprocessing import StandardScaler

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

1.2 Add Directories To Path

[2]:
```
# Add the source subdirectory to the system path to allow import config from␣
 ↪settings.py
current_directory = Path(os.getcwd())
website_base_directory = current_directory.parent.parent.parent
src_directory = website_base_directory / "src"
sys.path.append(str(src_directory)) if str(src_directory) not in sys.path else␣
 ↪None

# Import settings.py
from settings import config

# Add configured directories from config to path
SOURCE_DIR = config("SOURCE_DIR")
sys.path.append(str(Path(SOURCE_DIR))) if str(Path(SOURCE_DIR)) not in sys.path␣
 ↪else None

# Add other configured directories
BASE_DIR = config("BASE_DIR")
CONTENT_DIR = config("CONTENT_DIR")
POSTS_DIR = config("POSTS_DIR")
PAGES_DIR = config("PAGES_DIR")
PUBLIC_DIR = config("PUBLIC_DIR")
SOURCE_DIR = config("SOURCE_DIR")
DATA_DIR = config("DATA_DIR")
DATA_MANUAL_DIR = config("DATA_MANUAL_DIR")

# Print system path
for i, path in enumerate(sys.path):
    print(f"{i}: {path}")
```

```
0: /usr/lib/python313.zip
1: /usr/lib/python3.13
2: /usr/lib/python3.13/lib-dynload
3:
4: /home/jared/python-virtual-envs/general-venv-p313/lib/python3.13/site-
packages
5:
/home/jared/Cloud_Storage/Dropbox/Websites/jaredszajkowski.github.io_congo/src
```

1.3 Track Index Dependencies

[3]:
```
# Create file to track markdown dependencies
dep_file = Path("index_dep.txt")
dep_file.write_text("")
```

[3]: 0

1.4 Python Functions

[4]:
```
from calc_vix_trade_pnl import calc_vix_trade_pnl
from df_info import df_info
from df_info_markdown import df_info_markdown
from export_track_md_deps import export_track_md_deps
from load_data import load_data
from pandas_set_decimal_places import pandas_set_decimal_places
from plot_timeseries import plot_timeseries
from plot_stats import plot_stats
from plot_vix_with_trades import plot_vix_with_trades
from yf_pull_data import yf_pull_data
```

1.5 Data Overview - VIX

1.5.1 Acquire CBOE Volatility Index (VIX) Data

[5]:
```
yf_pull_data(
    base_directory=DATA_DIR,
    ticker="^VIX",
    source="Yahoo_Finance",
    asset_class="Indices",
    excel_export=True,
    pickle_export=True,
    output_confirmation=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
2026-01-26  16.15  17.389999  15.8  16.9       0

Yahoo Finance data complete for ^VIX
--------------------
```

[5]:

Date	Close	High	Low	Open	Volume
1990-01-02	17.240000	17.240000	17.240000	17.240000	0
1990-01-03	18.190001	18.190001	18.190001	18.190001	0
1990-01-04	19.219999	19.219999	19.219999	19.219999	0
1990-01-05	20.110001	20.110001	20.110001	20.110001	0
1990-01-08	20.260000	20.260000	20.260000	20.260000	0

```
…                …          …          …          …          …
2026-01-20  20.090000  20.990000  18.639999  19.940001          0
2026-01-21  16.900000  20.809999  16.670000  19.309999          0
2026-01-22  15.640000  16.670000  15.270000  16.650000          0
2026-01-23  16.090000  16.209999  15.300000  15.680000          0
2026-01-26  16.150000  17.389999  15.800000  16.900000          0

[9083 rows x 5 columns]
```

1.5.2 Load Data - VIX

[6]:
```
# Set decimal places
pandas_set_decimal_places(2)

# VIX
vix = load_data(
    base_directory=DATA_DIR,
    ticker="^VIX",
    source="Yahoo_Finance",
    asset_class="Indices",
    timeframe="Daily",
    file_format="excel",
)

# 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)

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

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

1.5.3 DataFrame Info - VIX

[7]:
```
df_info(vix)
```

```
The columns, shape, and data types are:
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 9083 entries, 1990-01-02 to 2026-01-26
Data columns (total 4 columns):
 #   Column  Non-Null Count  Dtype
```

```
---  ------  --------------  -----
 0   Close   9083 non-null   float64
 1   High    9083 non-null   float64
 2   Low     9083 non-null   float64
 3   Open    9083 non-null   float64
dtypes: float64(4)
memory usage: 354.8 KB
None
The first 5 rows are:
```

Date	Close	High	Low	Open
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:
```

Date	Close	High	Low	Open
2026-01-20	20.09	20.99	18.64	19.94
2026-01-21	16.90	20.81	16.67	19.31
2026-01-22	15.64	16.67	15.27	16.65
2026-01-23	16.09	16.21	15.30	15.68
2026-01-26	16.15	17.39	15.80	16.90

[8]:
```
# Copy this <!-- INSERT_01_VIX_DF_Info_HERE --> to index_temp.md
export_track_md_deps(
    dep_file=dep_file,
    md_filename="01_VIX_DF_Info.md",
    content=df_info_markdown(vix),
    output_type="markdown",
)
```

```
 Exported and tracked: 01_VIX_DF_Info.md
```

1.5.4 Statistics - VIX

[9]:
```
vix_stats = vix.describe()
num_std = range(-1, 6)  # Adjusted to include -1 to 5
for num in num_std:
    vix_stats.loc[f"mean + {num} std"] = {
        'Open': vix_stats.loc['mean']['Open'] + num * vix_stats.
 ↪loc['std']['Open'],
        'High': vix_stats.loc['mean']['High'] + num * vix_stats.
 ↪loc['std']['High'],
        'Low': vix_stats.loc['mean']['Low'] + num * vix_stats.loc['std']['Low'],
```

```
        'Close': vix_stats.loc['mean']['Close'] + num * vix_stats.
 ↪loc['std']['Close'],
    }

display(vix_stats)
```

	Close	High	Low	Open
count	9083.00	9083.00	9083.00	9083.00
mean	19.45	20.36	18.78	19.54
std	7.78	8.34	7.34	7.85
min	9.14	9.31	8.56	9.01
25%	13.94	14.60	13.45	13.98
50%	17.58	18.31	16.99	17.64
75%	22.73	23.73	22.06	22.89
max	82.69	89.53	72.76	82.69
mean + -1 std	11.67	12.03	11.44	11.69
mean + 0 std	19.45	20.36	18.78	19.54
mean + 1 std	27.23	28.70	26.11	27.40
mean + 2 std	35.01	37.03	33.45	35.25
mean + 3 std	42.79	45.37	40.79	43.10
mean + 4 std	50.57	53.70	48.12	50.96
mean + 5 std	58.35	62.04	55.46	58.81

[10]:
```
# Copy this <!-- INSERT_01_VIX_Stats_HERE --> to index_temp.md
export_track_md_deps(
    dep_file=dep_file,
    md_filename="01_VIX_Stats.md",
    content=vix_stats.to_markdown(floatfmt=".2f"),
    output_type="markdown",
)
```

```
Exported and tracked: 01_VIX_Stats.md
```

[11]:
```
# Group by year and calculate mean and std for OHLC
vix_stats_by_year = vix.groupby(vix.index.year)[["Open", "High", "Low",␣
 ↪"Close"]].agg(["mean", "std" ,"min", "max"])

# Flatten the column MultiIndex
vix_stats_by_year.columns = ['_'.join(col).strip() for col in vix_stats_by_year.
 ↪columns.values]
vix_stats_by_year.index.name = "Year"

display(vix_stats_by_year)
```

Year	Open_mean	Open_std	Open_min	Open_max	High_mean	High_std	High_min	\
1990	23.06	4.74	14.72	36.47	23.06	4.74	14.72	
1991	18.38	3.68	13.95	36.20	18.38	3.68	13.95	
1992	15.23	2.26	10.29	20.67	16.03	2.19	11.90	

1993	12.70	1.37	9.18	16.20	13.34	1.40	9.55
1994	13.79	2.06	9.86	23.61	14.58	2.28	10.31
1995	12.27	1.03	10.29	15.79	12.93	1.07	10.95
1996	16.31	1.92	11.24	23.90	16.99	2.12	12.29
1997	22.43	4.33	16.67	45.69	23.11	4.56	18.02
1998	25.68	6.96	16.42	47.95	26.61	7.36	16.50
1999	24.39	2.90	18.05	32.62	25.20	3.01	18.48
2000	23.41	3.43	16.81	33.70	24.10	3.66	17.06
2001	26.04	4.98	19.21	48.93	26.64	5.19	19.37
2002	27.53	7.03	17.23	48.17	28.28	7.25	17.51
2003	22.21	5.31	15.59	35.21	22.61	5.35	16.19
2004	15.59	1.93	11.41	21.06	16.05	2.02	11.64
2005	12.84	1.44	10.23	18.33	13.28	1.59	10.48
2006	12.90	2.18	9.68	23.45	13.33	2.46	10.06
2007	17.59	5.36	9.99	32.68	18.44	5.76	10.26
2008	32.83	16.41	16.30	80.74	34.57	17.83	17.84
2009	31.75	9.20	19.54	52.65	32.78	9.61	19.67
2010	22.73	5.29	15.44	47.66	23.69	5.82	16.00
2011	24.27	8.17	14.31	46.18	25.40	8.78	14.99
2012	17.93	2.60	13.68	26.35	18.59	2.72	14.08
2013	14.29	1.67	11.52	20.87	14.82	1.88	11.75
2014	14.23	2.65	10.40	29.26	14.95	3.02	10.76
2015	16.71	3.99	11.77	31.91	17.79	5.03	12.22
2016	16.01	4.05	11.32	29.01	16.85	4.40	11.49
2017	11.14	1.34	9.23	16.19	11.72	1.54	9.52
2018	16.63	5.01	9.01	37.32	18.03	6.12	9.31
2019	15.57	2.74	11.55	27.54	16.41	3.06	11.79
2020	29.52	12.45	12.20	82.69	31.46	13.89	12.42
2021	19.83	3.47	15.02	35.16	21.12	4.22	15.54
2022	25.98	4.30	16.57	37.50	27.25	4.59	17.81
2023	17.12	3.17	11.96	27.77	17.83	3.58	12.46
2024	15.69	3.14	11.53	33.71	16.65	4.73	12.23
2025	19.19	5.57	14.09	60.13	20.44	6.74	14.16
2026	16.22	1.47	14.85	19.94	16.83	1.77	15.21

Year	High_max	Low_mean	Low_std	Low_min	Low_max	Close_mean	Close_std	\
1990	36.47	23.06	4.74	14.72	36.47	23.06	4.74	
1991	36.20	18.38	3.68	13.95	36.20	18.38	3.68	
1992	25.13	14.85	2.14	10.29	19.67	15.45	2.12	
1993	18.31	12.25	1.28	8.89	15.77	12.69	1.33	
1994	28.30	13.38	1.99	9.59	23.61	13.93	2.07	
1995	16.99	11.96	0.98	10.06	14.97	12.39	0.97	
1996	27.05	15.94	1.82	11.11	21.43	16.44	1.94	
1997	48.64	21.85	3.98	16.36	36.43	22.38	4.14	
1998	49.53	24.89	6.58	16.10	45.58	25.60	6.86	
1999	33.66	23.75	2.76	17.07	31.13	24.37	2.88	
2000	34.31	22.75	3.19	16.28	30.56	23.32	3.41	

2001	49.35	25.22	4.61	18.74	42.66	25.75	4.78
2002	48.46	26.60	6.64	17.02	42.05	27.29	6.91
2003	35.66	21.64	5.18	14.66	33.99	21.98	5.24
2004	22.67	15.05	1.79	11.14	20.61	15.48	1.92
2005	18.59	12.39	1.32	9.88	16.41	12.81	1.47
2006	23.81	12.38	1.96	9.39	21.45	12.81	2.25
2007	37.50	16.75	4.95	9.70	30.44	17.54	5.36
2008	89.53	30.96	14.96	15.82	72.76	32.69	16.38
2009	57.36	30.50	8.63	19.25	49.27	31.48	9.08
2010	48.20	21.69	4.61	15.23	40.30	22.55	5.27
2011	48.00	23.15	7.59	14.27	41.51	24.20	8.14
2012	27.73	17.21	2.37	13.30	25.72	17.80	2.54
2013	21.91	13.80	1.51	11.05	19.04	14.23	1.74
2014	31.06	13.61	2.21	10.28	24.64	14.17	2.62
2015	53.29	15.85	3.65	10.88	29.91	16.67	4.34
2016	32.09	15.16	3.66	10.93	26.67	15.83	3.97
2017	17.28	10.64	1.16	8.56	14.97	11.09	1.36
2018	50.30	15.53	4.25	8.92	29.66	16.64	5.09
2019	28.53	14.76	2.38	11.03	24.05	15.39	2.61
2020	85.47	27.50	10.85	11.75	70.37	29.25	12.34
2021	37.51	18.65	2.93	14.10	29.24	19.66	3.62
2022	38.94	24.69	3.91	16.34	33.11	25.62	4.22
2023	30.81	16.36	2.89	11.81	24.00	16.87	3.14
2024	65.73	14.92	2.58	10.62	24.02	15.61	3.36
2025	60.13	18.07	4.22	13.38	38.58	18.96	5.32
2026	20.99	15.40	1.06	14.43	18.64	15.87	1.34

Year	Close_min	Close_max
1990	14.72	36.47
1991	13.95	36.20
1992	11.51	21.02
1993	9.31	17.30
1994	9.94	23.87
1995	10.36	15.74
1996	12.00	21.99
1997	17.09	38.20
1998	16.23	45.74
1999	17.42	32.98
2000	16.53	33.49
2001	18.76	43.74
2002	17.40	45.08
2003	15.58	34.69
2004	11.23	21.58
2005	10.23	17.74
2006	9.90	23.81
2007	9.89	31.09
2008	16.30	80.86

```
2009      19.47      56.65
2010      15.45      45.79
2011      14.62      48.00
2012      13.45      26.66
2013      11.30      20.49
2014      10.32      25.27
2015      11.95      40.74
2016      11.27      28.14
2017       9.14      16.04
2018       9.15      37.32
2019      11.54      25.45
2020      12.10      82.69
2021      15.01      37.21
2022      16.60      36.45
2023      12.07      26.52
2024      11.86      38.57
2025      13.47      52.33
2026      14.49      20.09
```

[12]:
```
# Copy this <!-- INSERT_01_VIX_Stats_By_Year_HERE --> to index_temp.md
export_track_md_deps(
    dep_file=dep_file,
    md_filename="01_VIX_Stats_By_Year.md",
    content=vix_stats_by_year.to_markdown(floatfmt=".2f"),
    output_type="markdown",
)
```

```
Exported and tracked: 01_VIX_Stats_By_Year.md
```

[13]:
```
# Group by month and calculate mean and std for OHLC
vix_stats_by_month = vix.groupby(vix.index.month)[["Open", "High", "Low",␣
 ↪"Close"]].agg(["mean", "std", "min", "max"])

# Flatten the column MultiIndex
vix_stats_by_month.columns = ['_'.join(col).strip() for col in␣
 ↪vix_stats_by_month.columns.values]
vix_stats_by_month.index.name = "Month"

display(vix_stats_by_month)
```

```
       Open_mean  Open_std  Open_min  Open_max  High_mean  High_std  High_min  \
Month
1          19.27      7.15      9.01     51.52      20.06      7.52      9.31
2          19.67      7.22     10.19     52.50      20.51      7.65     10.26
3          20.47      9.63     10.59     82.69      21.39     10.49     11.24
4          19.43      7.48     10.39     60.13      20.24      7.93     10.89
5          18.60      6.04      9.75     47.66      19.40      6.43     10.14
6          18.46      5.75      9.79     44.09      19.15      6.02     10.28
```

```
7          17.83      5.67      9.18      48.17      18.53      5.90      9.52
8          19.09      6.67     10.04      45.34      20.03      7.38     10.32
9          20.37      8.23      9.59      48.93      21.21      8.55      9.83
10         21.72     10.16      9.23      79.13      22.73     10.97      9.62
11         20.34      9.54      9.31      80.74      21.06      9.91      9.74
12         19.24      8.16      9.36      66.68      19.98      8.43      9.55

       High_max  Low_mean  Low_std  Low_min  Low_max  Close_mean  Close_std  \
Month
1         57.36     18.54     6.81     8.92    49.27       19.15       7.11
2         53.16     18.90     6.81     9.70    48.97       19.58       7.13
3         85.47     19.54     8.65    10.53    70.37       20.35       9.56
4         60.59     18.65     6.88    10.22    52.76       19.29       7.28
5         48.20     17.89     5.63     9.56    40.30       18.51       5.96
6         44.44     17.73     5.40     9.37    34.97       18.34       5.68
7         48.46     17.21     5.41     8.84    42.05       17.76       5.60
8         65.73     18.35     6.32     9.52    41.77       19.09       6.80
9         49.35     19.62     7.82     9.36    43.74       20.29       8.12
10        89.53     20.82     9.40     9.11    67.80       21.64      10.12
11        81.48     19.53     8.91     8.56    72.76       20.16       9.41
12        68.60     18.53     7.79     8.89    62.31       19.18       8.07

       Close_min  Close_max
Month
1           9.15      56.65
2          10.02      52.62
3          10.74      82.69
4          10.36      57.06
5           9.77      45.79
6           9.75      40.79
7           9.36      44.92
8           9.93      48.00
9           9.51      46.72
10          9.19      80.06
11          9.14      80.86
12          9.31      68.51
```

[14]:
```python
# Copy this <!-- INSERT_01_VIX_Stats_By_Month_HERE --> to index_temp.md
export_track_md_deps(
    dep_file=dep_file,
    md_filename="01_VIX_Stats_By_Month.md",
    content=vix_stats_by_month.to_markdown(floatfmt=".2f"),
    output_type="markdown",
)
```

```
Exported and tracked: 01_VIX_Stats_By_Month.md
```

1.5.5 Deciles - VIX

[15]:
```
vix_deciles = vix.quantile(np.arange(0, 1.1, 0.1))
display(vix_deciles)
```

	Close	High	Low	Open
0.00	9.14	9.31	8.56	9.01
0.10	12.14	12.65	11.73	12.15
0.20	13.30	13.90	12.89	13.35
0.30	14.67	15.36	14.17	14.74
0.40	16.10	16.77	15.57	16.15
0.50	17.58	18.31	16.99	17.64
0.60	19.47	20.32	18.89	19.59
0.70	21.54	22.54	20.89	21.67
0.80	24.23	25.21	23.35	24.31
0.90	28.62	29.90	27.62	28.78
1.00	82.69	89.53	72.76	82.69

[16]:
```
# Copy this <!-- INSERT_01_VIX_Deciles_HERE --> to index_temp.md
export_track_md_deps(
    dep_file=dep_file,
    md_filename="01_VIX_Deciles.md",
    content=vix_deciles.to_markdown(floatfmt=".2f"),
    output_type="markdown",
)
```

```
 Exported and tracked: 01_VIX_Deciles.md
```

[17]:
```
# Group by year for deciles
vix_deciles_by_year = vix.groupby(vix.index.year)[["Open", "High", "Low",␣
 ↪"Close"]].quantile(np.arange(0, 1.1, 0.1))

display(vix_deciles_by_year)
```

		Open	High	Low	Close
Date					
1990	0.00	14.72	14.72	14.72	14.72
	0.10	17.18	17.18	17.18	17.18
	0.20	18.47	18.47	18.47	18.47
	0.30	20.08	20.08	20.08	20.08
	0.40	21.15	21.15	21.15	21.15
…		…	…	…	…
2026	0.60	16.06	16.54	15.30	15.86
	0.70	16.43	16.66	15.30	16.03
	0.80	16.65	17.39	15.80	16.15
	0.90	18.10	19.45	16.44	16.82
	1.00	19.94	20.99	18.64	20.09

[407 rows x 4 columns]

[18]:
```
# Copy this <!-- INSERT_01_VIX_Deciles_By_Year_HERE --> to index_temp.md
export_track_md_deps(
    dep_file=dep_file,
    md_filename="01_VIX_Deciles_By_Year.md",
    content=vix_deciles_by_year.to_markdown(floatfmt=".2f"),
    output_type="markdown",
)
```

```
Exported and tracked: 01_VIX_Deciles_By_Year.md
```

[19]:
```
current_year = datetime.now().year
last_year = current_year - 1

print(f"Last year: {last_year}")
vix_deciles_last_year = vix_deciles_by_year.loc[last_year]
display(vix_deciles_last_year)

print(f"Current year: {current_year}")
vix_deciles_current_year = vix_deciles_by_year.loc[current_year]
display(vix_deciles_current_year)
```

```
Last year: 2025
```

	Open	High	Low	Close
0.00	14.09	14.16	13.38	13.47
0.10	15.15	15.80	14.74	15.04
0.20	15.88	16.50	15.28	15.72
0.30	16.40	17.09	15.77	16.31
0.40	16.79	17.48	16.19	16.64
0.50	17.45	18.21	16.61	17.20
0.60	18.25	19.31	17.42	17.96
0.70	19.52	21.01	18.23	19.13
0.80	21.16	22.84	19.57	21.21
0.90	24.57	26.37	23.29	24.66
1.00	60.13	60.13	38.58	52.33

```
Current year: 2026
```

	Open	High	Low	Close
0.00	14.85	15.21	14.43	14.49
0.10	14.97	15.35	14.55	14.63
0.20	15.14	15.48	14.65	14.90
0.30	15.40	15.83	14.79	15.25
0.40	15.68	16.21	15.03	15.45
0.50	15.68	16.40	15.21	15.74
0.60	16.06	16.54	15.30	15.86
0.70	16.43	16.66	15.30	16.03
0.80	16.65	17.39	15.80	16.15
0.90	18.10	19.45	16.44	16.82
1.00	19.94	20.99	18.64	20.09

[20]:
```
# Copy this <!-- INSERT_01_Last_Year_HERE --> to index_temp.md
export_track_md_deps(
    dep_file=dep_file,
    md_filename="01_Last_Year.md",
    content=f"{last_year}",
    output_type="markdown",
)

# Copy this <!-- INSERT_01_VIX_Deciles_Last_Year_HERE --> to index_temp.md
export_track_md_deps(
    dep_file=dep_file,
    md_filename="01_VIX_Deciles_Last_Year.md",
    content=vix_deciles_last_year.to_markdown(floatfmt=".2f"),
    output_type="markdown",
)
```

```
Exported and tracked: 01_Last_Year.md
Exported and tracked: 01_VIX_Deciles_Last_Year.md
```

[21]:
```
# Copy this <!-- INSERT_01_Current_Year_HERE --> to index_temp.md
export_track_md_deps(
    dep_file=dep_file,
    md_filename="01_Current_Year.md",
    content=f"{current_year}",
    output_type="markdown",
)

# Copy this <!-- INSERT_01_VIX_Deciles_Current_Year_HERE --> to index_temp.md
export_track_md_deps(
    dep_file=dep_file,
    md_filename="01_VIX_Deciles_Current_Year.md",
    content=vix_deciles_current_year.to_markdown(floatfmt=".2f"),
    output_type="markdown",
)
```

```
Exported and tracked: 01_Current_Year.md
Exported and tracked: 01_VIX_Deciles_Current_Year.md
```

1.6 Time Between Levels

[22]:
```
import pandas as pd
import math
from typing import Literal

Op = Literal["==", ">=", ">", "<=", "<"]

def compare(value: float, threshold: float, op: Op) -> bool:
    if op == "==":
```

```
        return value == threshold
    if op == ">=":
        return value >= threshold
    if op == ">":
        return value > threshold
    if op == "<=":
        return value <= threshold
    if op == "<":
        return value < threshold
    raise ValueError(f"Unsupported op: {op}")

def compute_waits(
    df: pd.DataFrame,
    high_col: str = "High",
    trigger_a: float = 20.0,
    trigger_b: float = 20.0,
    op_a: Op = ">=",
    op_b: Op = ">=",
    strictly_after: bool = True,
) -> pd.DataFrame:
    """
    For each day i where df[high_col] op_a trigger_a, find the next day j
    (j > i if strictly_after else j >= i) where df[high_col] op_b trigger_b.
    """
    df = df.sort_index()
    idx = df.index
    highs = df[high_col].values
    n = len(df)

    rows = []
    for i in range(n):
        if compare(highs[i], trigger_a, op_a):
            start_j = i + 1 if strictly_after else i
            j_found = None
            for j in range(start_j, n):
                if compare(highs[j], trigger_b, op_b):
                    j_found = j
                    break

            if j_found is None:
                next_date = pd.NaT if isinstance(idx, pd.DatetimeIndex) else␣
 ↪None
                next_high = math.nan
                wait_td = math.nan
                wait_cd = math.nan
            else:
                next_date = idx[j_found]
```

```
                next_high = float(highs[j_found])
                wait_td = j_found - i
                if isinstance(idx, pd.DatetimeIndex):
                    wait_cd = (idx[j_found].normalize() - idx[i].normalize()).
↪days
                else:
                    wait_cd = math.nan

            rows.append(
                {
                    "date_a": idx[i],
                    "high_at_a": float(highs[i]),
                    "date_b": next_date,
                    "high_at_b": next_high,
                    "wait_trading_days": wait_td,
                    "wait_calendar_days": wait_cd,
                }
            )

    return pd.DataFrame(rows)
```

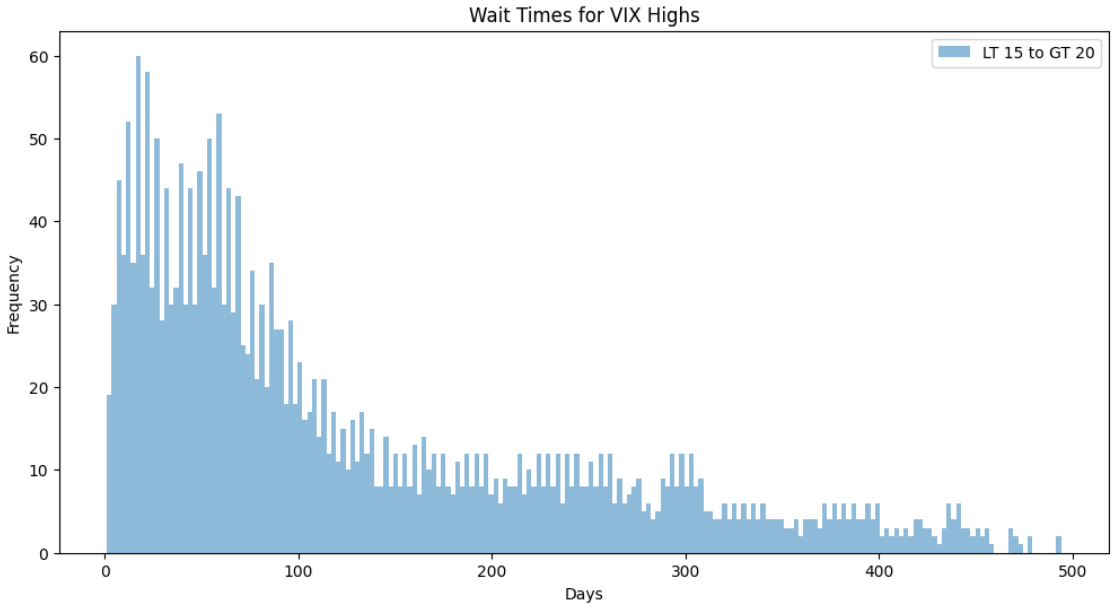
[23]:
```
# When daily high <= 15, how long until next daily high >= 20?
res_lt15_to_gt20 = compute_waits(
    df=vix,
    high_col="High",
    trigger_a=15,
    trigger_b=20,
    op_a="<=",
    op_b=">=",
    strictly_after=True,
)

res_lt15_to_gt20
```

[23]:

	date_a	high_at_a	date_b	high_at_b	wait_trading_days	\
0	1990-06-21	14.72	1990-07-23	23.68	21	
1	1991-03-14	14.94	1991-04-09	20.12	17	
2	1991-03-15	14.90	1991-04-09	20.12	16	
3	1991-08-13	14.73	1991-08-19	21.19	4	
4	1991-08-22	14.59	1991-11-15	21.18	60	
…	…	…	…	…	…	
2530	2025-09-12	14.97	2025-10-10	22.44	20	
2531	2025-12-23	14.45	2026-01-20	20.99	17	
2532	2025-12-24	14.16	2026-01-20	20.99	16	
2533	2025-12-26	14.29	2026-01-20	20.99	15	
2534	2025-12-30	14.62	2026-01-20	20.99	13	

```
      wait_calendar_days
0                     32
1                     26
2                     25
3                      6
4                     85
…                    …
2530                  28
2531                  28
2532                  27
2533                  25
2534                  21

[2535 rows x 6 columns]
```

[24]:
```
# Plot histogram for wait times
import matplotlib.pyplot as plt

plt.figure(figsize=(12, 6))
plt.hist(res_lt15_to_gt20['wait_trading_days'].dropna(), bins=200, alpha=0.5,␣
 ↪label='LT 15 to GT 20')
plt.xlabel('Days')
plt.ylabel('Frequency')
plt.title('Wait Times for VIX Highs')
plt.legend()
plt.show()
```



[25]:
```python
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from typing import Optional, Tuple

def compute_wait_cdf(
    waits_df: pd.DataFrame,
    column: str = "wait_trading_days",
) -> pd.DataFrame:
    """
    Compute the empirical CDF for wait times.

    Returns a DataFrame with:
      - 'wait': unique wait values (sorted)
      - 'count': frequency for each wait
      - 'cdf': cumulative probability P(Wait <= x)
      - 'ccdf': complementary CDF = 1 - cdf (P(Wait > x))
    """
    # Drop NaNs; don't cast to int (keep original type)
    waits = waits_df[column].dropna().to_numpy()
    if waits.size == 0:
        return pd.DataFrame(columns=["wait", "count", "cdf", "ccdf"])

    # Unique values and counts
    vals, counts = np.unique(waits, return_counts=True)
    cum_counts = np.cumsum(counts)
    n = waits.size
    cdf = cum_counts / n
    ccdf = 1.0 - cdf

    out = pd.DataFrame(
        {"wait": vals, "count": counts, "cdf": cdf, "ccdf": ccdf}
    )
    return out
```

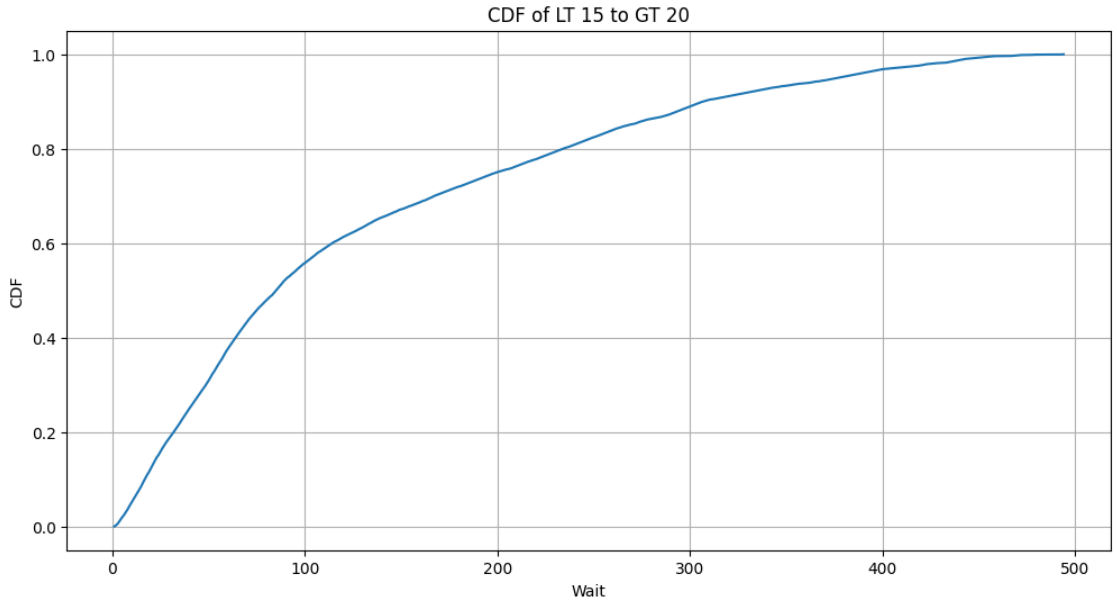
[26]:
```python
cdf_df = compute_wait_cdf(
    waits_df=res_lt15_to_gt20,
    column="wait_trading_days")

cdf_df
```

[26]:

	wait	count	cdf	ccdf
0	1	1	0.00	1.00
1	2	7	0.00	1.00
2	3	11	0.01	0.99
3	4	15	0.01	0.99
4	5	15	0.02	0.98

```
..    …     …  …    …
461   472      1 1.00  0.00
462   478      1 1.00  0.00
463   479      1 1.00  0.00
464   493      1 1.00  0.00
465   494      1 1.00  0.00

[466 rows x 4 columns]
```

[27]:
```python
# Plot CDF
plt.figure(figsize=(12, 6))
plt.plot(cdf_df['wait'], cdf_df['cdf'])
plt.title('CDF of LT 15 to GT 20')
plt.xlabel('Wait')
plt.ylabel('CDF')
plt.grid()
plt.show()
```



[28]:
```python
import pandas as pd
import numpy as np

def empirical_hit_probabilities(
    df: pd.DataFrame,
    high_col: str,
    thresholds,
    horizons,
) -> pd.DataFrame:
```

```
    """
    Compute empirical probability of reaching a threshold high within given␣
↪horizons.

    Parameters
    ----------
    df : pd.DataFrame
        Sorted daily data with a High column.
    high_col : str
        Name of the column with daily highs.
    thresholds : list of floats
        Target levels (e.g. [18,19,20,21,22]).
    horizons : list of ints
        Lookahead windows in trading days.

    Returns
    -------
    pd.DataFrame
        Rows = horizons, Cols = thresholds, entries = probability [0,1].
    """

    df = df.sort_index()
    highs = df[high_col].values
    n = len(highs)

    probs = pd.DataFrame(index=horizons, columns=thresholds, dtype=float)

    for h in horizons:
        valid_starts = n - h  # last h days have incomplete windows
        if valid_starts <= 0:
            continue
        window_max = np.array([highs[i+1:i+h+1].max() for i in␣
↪range(valid_starts)])
        # note: exclude same day (i+1:...) so it's "future" only
        for thr in thresholds:
            hits = (window_max >= thr).sum()
            probs.loc[h, thr] = hits / valid_starts

    return probs
```

[29]:
```
probs = empirical_hit_probabilities(
    df=vix,
    high_col="High",
    thresholds=range(15, 35),
    horizons=range(5, 101, 5),
)
```

```
display(probs)
```

```
      15   16   17   18   19   20   21   22   23   24   25   26   27   28  \
5   0.78 0.73 0.66 0.59 0.54 0.49 0.44 0.39 0.35 0.30 0.26 0.23 0.20 0.18
10  0.83 0.78 0.71 0.64 0.59 0.54 0.49 0.43 0.40 0.35 0.30 0.27 0.25 0.22
15  0.85 0.81 0.75 0.68 0.62 0.58 0.53 0.47 0.43 0.38 0.34 0.31 0.28 0.26
20  0.87 0.83 0.77 0.71 0.65 0.60 0.56 0.49 0.46 0.41 0.37 0.33 0.31 0.28
25  0.89 0.85 0.80 0.74 0.68 0.63 0.59 0.52 0.49 0.43 0.39 0.36 0.34 0.31
30  0.91 0.87 0.81 0.76 0.70 0.65 0.61 0.54 0.51 0.45 0.42 0.39 0.36 0.33
35  0.92 0.89 0.83 0.77 0.72 0.67 0.63 0.56 0.53 0.47 0.44 0.41 0.38 0.35
40  0.93 0.90 0.84 0.79 0.74 0.69 0.65 0.58 0.55 0.49 0.46 0.43 0.40 0.37
45  0.94 0.91 0.85 0.80 0.75 0.71 0.67 0.60 0.57 0.51 0.47 0.44 0.42 0.39
50  0.94 0.92 0.86 0.81 0.77 0.72 0.69 0.61 0.58 0.52 0.49 0.46 0.44 0.40
55  0.95 0.93 0.87 0.82 0.78 0.74 0.71 0.63 0.60 0.53 0.50 0.47 0.45 0.42
60  0.95 0.93 0.88 0.83 0.80 0.75 0.72 0.64 0.61 0.54 0.51 0.49 0.47 0.43
65  0.96 0.94 0.89 0.84 0.81 0.76 0.74 0.65 0.62 0.55 0.53 0.50 0.48 0.44
70  0.96 0.94 0.90 0.85 0.82 0.78 0.75 0.66 0.63 0.56 0.54 0.51 0.49 0.46
75  0.97 0.95 0.91 0.86 0.83 0.79 0.77 0.67 0.65 0.57 0.55 0.52 0.51 0.47
80  0.97 0.95 0.91 0.87 0.84 0.80 0.78 0.68 0.66 0.58 0.56 0.54 0.52 0.48
85  0.97 0.96 0.92 0.87 0.84 0.80 0.79 0.69 0.67 0.59 0.57 0.55 0.53 0.49
90  0.98 0.96 0.92 0.88 0.85 0.81 0.80 0.70 0.68 0.60 0.58 0.56 0.54 0.50
95  0.98 0.97 0.93 0.88 0.85 0.82 0.81 0.71 0.69 0.61 0.59 0.57 0.55 0.51
100 0.98 0.97 0.93 0.89 0.86 0.83 0.81 0.72 0.69 0.62 0.59 0.57 0.56 0.52

      29   30   31   32   33   34
5   0.16 0.14 0.12 0.10 0.09 0.08
10  0.19 0.17 0.15 0.13 0.11 0.10
15  0.22 0.20 0.17 0.15 0.13 0.12
20  0.25 0.22 0.19 0.16 0.15 0.14
25  0.27 0.24 0.22 0.18 0.17 0.15
30  0.29 0.26 0.23 0.20 0.19 0.17
35  0.31 0.28 0.25 0.22 0.20 0.19
40  0.33 0.29 0.27 0.23 0.22 0.20
45  0.34 0.31 0.28 0.25 0.23 0.21
50  0.36 0.32 0.30 0.26 0.24 0.23
55  0.37 0.34 0.31 0.27 0.26 0.24
60  0.38 0.35 0.32 0.29 0.27 0.25
65  0.40 0.37 0.34 0.30 0.28 0.26
70  0.41 0.38 0.35 0.31 0.29 0.28
75  0.42 0.39 0.36 0.32 0.30 0.29
80  0.43 0.41 0.37 0.33 0.31 0.30
85  0.44 0.42 0.39 0.35 0.32 0.31
90  0.45 0.43 0.40 0.36 0.34 0.32
95  0.46 0.44 0.41 0.37 0.35 0.33
100 0.47 0.46 0.42 0.38 0.36 0.34
```

[30]:
```python
import pandas as pd
import numpy as np

def conditional_hit_probabilities(
    df: pd.DataFrame,
    today_high: float,
    high_col: str,
    thresholds,
    horizons,
    tolerance: float,  # how close history must be to today's high
) -> pd.DataFrame:

    """
    Conditional probability of hitting thresholds within horizons,
    given today's high is near `today_high`.

    Parameters
    ----------
    df : pd.DataFrame
        Daily data with highs.
    today_high : float
        Today's observed high.
    high_col : str
        Column containing the daily highs.
    thresholds : list of floats
        Target levels to evaluate (e.g., [18,19,20,...]).
    horizons : list of ints
        Lookahead windows (in trading days).
    tolerance : float
        Acceptable deviation from today's high when finding historical␣
 ↪analogues.

    Returns
    -------
    pd.DataFrame
        Probabilities indexed by horizon (rows) and thresholds (columns).
    """

    df = df.sort_index()
    highs = df[high_col].values
    n = len(highs)

    # Find indices where the high ~ today's high
    candidates = np.where((highs >= today_high - tolerance) & (highs <=␣
 ↪today_high + tolerance))[0]
    if len(candidates) == 0:
```

```
        raise ValueError("No historical days found within tolerance of today's␣
↪high")

    probs = pd.DataFrame(index=horizons, columns=thresholds, dtype=float)

    for h in horizons:
        valid_hits = 0
        total = 0
        for i in candidates:
            if i + h < n:  # need full window
                window_max = highs[i+1:i+h+1].max()  # strictly future days
                for thr in thresholds:
                    if np.isnan(probs.loc[h, thr]):
                        probs.loc[h, thr] = 0.0
                    if window_max >= thr:
                        probs.loc[h, thr] += 1
                total += 1
        if total > 0:
            probs.loc[h] /= total  # normalize to probability
        else:
            probs.loc[h] = np.nan  # no valid examples

    return probs
```

[31]:
```
# Get yesterday's high as an example
yesterday = vix.iloc[-2]
yesterday_high = vix['High'].iloc[-2]

display(yesterday)
display(yesterday_high)

cond_probs = conditional_hit_probabilities(
    df=vix,
    today_high=yesterday_high,
    high_col="High",
    thresholds=range(15, 31),
    horizons=range(5, 71, 5),
    tolerance=0.25
)

display(cond_probs)
```

```
Close   16.09
High    16.21
Low     15.30
Open    15.68
Name: 2026-01-23 00:00:00, dtype: float64
```

```
np.float64(16.20999908447266)
```

```
     15   16   17   18   19   20   21   22   23   24   25   26   27   28   29  \
5  0.96 0.80 0.46 0.23 0.16 0.08 0.07 0.03 0.02 0.01 0.01 0.01 0.01 0.01 0.00
10 0.97 0.88 0.60 0.39 0.28 0.19 0.16 0.08 0.06 0.04 0.04 0.03 0.02 0.01 0.01
15 0.98 0.91 0.71 0.51 0.40 0.30 0.23 0.16 0.14 0.10 0.09 0.08 0.06 0.05 0.04
20 0.98 0.93 0.77 0.60 0.49 0.38 0.31 0.22 0.19 0.14 0.14 0.11 0.09 0.08 0.06
25 0.98 0.93 0.81 0.66 0.54 0.43 0.36 0.26 0.23 0.19 0.18 0.15 0.13 0.12 0.08
30 0.99 0.95 0.85 0.72 0.60 0.48 0.39 0.30 0.26 0.22 0.21 0.19 0.16 0.14 0.11
35 0.99 0.96 0.87 0.76 0.65 0.52 0.44 0.34 0.31 0.26 0.24 0.21 0.18 0.16 0.12
40 0.99 0.96 0.88 0.78 0.70 0.56 0.50 0.38 0.35 0.30 0.27 0.24 0.20 0.17 0.13
45 0.99 0.96 0.89 0.79 0.72 0.59 0.53 0.41 0.37 0.32 0.29 0.25 0.22 0.18 0.14
50 0.99 0.97 0.89 0.80 0.74 0.61 0.55 0.43 0.39 0.33 0.30 0.26 0.24 0.19 0.15
55 0.99 0.97 0.90 0.81 0.76 0.64 0.59 0.46 0.41 0.35 0.31 0.29 0.26 0.20 0.16
60 0.99 0.97 0.90 0.82 0.78 0.67 0.62 0.48 0.43 0.35 0.32 0.31 0.28 0.22 0.16
65 0.99 0.98 0.91 0.83 0.79 0.68 0.63 0.50 0.44 0.37 0.34 0.32 0.29 0.23 0.17
70 0.99 0.98 0.91 0.84 0.80 0.70 0.65 0.52 0.46 0.39 0.36 0.35 0.31 0.25 0.19

     30
5  0.00
10 0.01
15 0.03
20 0.05
25 0.07
30 0.09
35 0.11
40 0.12
45 0.13
50 0.15
55 0.16
60 0.16
65 0.17
70 0.19
```

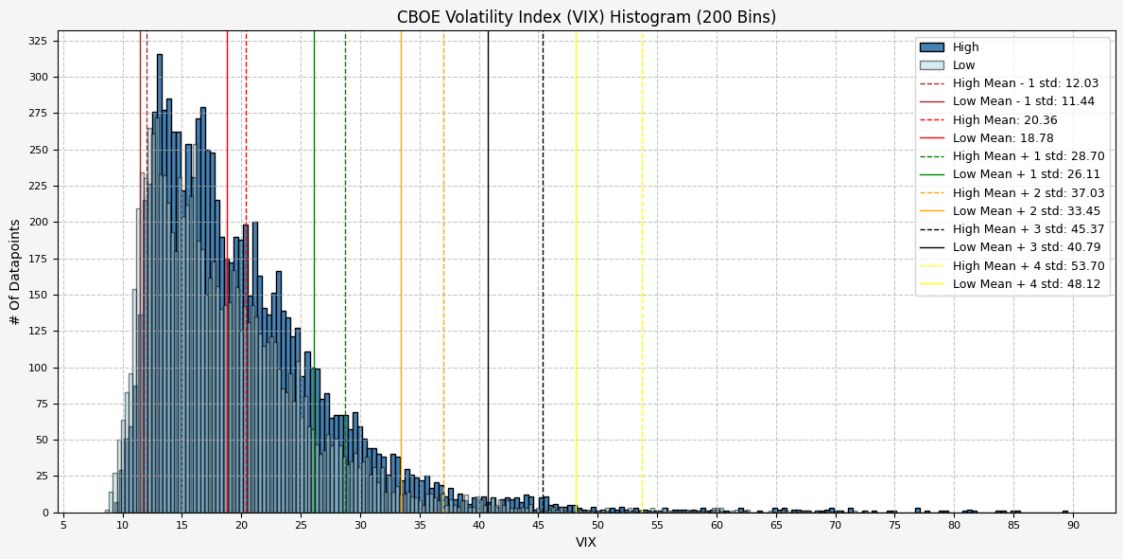
1.7 Plots - VIX

1.7.1 Histogram Distribution - VIX

[32]:
```
# Plotting
plt.figure(figsize=(12, 6), facecolor="#F5F5F5")

# Histogram
plt.hist([vix['High']], label=['High'], bins=200, edgecolor='black',␣
 ↪color='steelblue', alpha=1)
plt.hist([vix['Low']], label=['Low'], bins=200, edgecolor='black',␣
 ↪color='lightblue', alpha=0.5)

# Plot a vertical line at the mean, mean + 1 std, and mean + 2 std
```

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

plt.axvline(vix_stats.loc['mean']['High'], color='red', linestyle='dashed',␣
 ↪linewidth=1, label=f'High Mean: {vix_stats.loc['mean']['High']:.2f}')
plt.axvline(vix_stats.loc['mean']['Low'], color='red', linestyle='solid',␣
 ↪linewidth=1, label=f'Low Mean: {vix_stats.loc['mean']['Low']:.2f}')

plt.axvline(vix_stats.loc['mean + 1 std']['High'], color='green',␣
 ↪linestyle='dashed', linewidth=1, label=f'High Mean + 1 std: {vix_stats.
 ↪loc['mean + 1 std']['High']:.2f}')
plt.axvline(vix_stats.loc['mean + 1 std']['Low'], color='green',␣
 ↪linestyle='solid', linewidth=1, label=f'Low Mean + 1 std: {vix_stats.
 ↪loc['mean + 1 std']['Low']:.2f}')

plt.axvline(vix_stats.loc['mean + 2 std']['High'], color='orange',␣
 ↪linestyle='dashed', linewidth=1, label=f'High Mean + 2 std: {vix_stats.
 ↪loc['mean + 2 std']['High']:.2f}')
plt.axvline(vix_stats.loc['mean + 2 std']['Low'], color='orange',␣
 ↪linestyle='solid', linewidth=1, label=f'Low Mean + 2 std: {vix_stats.
 ↪loc['mean + 2 std']['Low']:.2f}')

plt.axvline(vix_stats.loc['mean + 3 std']['High'], color='black',␣
 ↪linestyle='dashed', linewidth=1, label=f'High Mean + 3 std: {vix_stats.
 ↪loc['mean + 3 std']['High']:.2f}')
plt.axvline(vix_stats.loc['mean + 3 std']['Low'], color='black',␣
 ↪linestyle='solid', linewidth=1, label=f'Low Mean + 3 std: {vix_stats.
 ↪loc['mean + 3 std']['Low']:.2f}')

plt.axvline(vix_stats.loc['mean + 4 std']['High'], color='yellow',␣
 ↪linestyle='dashed', linewidth=1, label=f'High Mean + 4 std: {vix_stats.
 ↪loc['mean + 4 std']['High']:.2f}')
plt.axvline(vix_stats.loc['mean + 4 std']['Low'], color='yellow',␣
 ↪linestyle='solid', linewidth=1, label=f'Low Mean + 4 std: {vix_stats.
 ↪loc['mean + 4 std']['Low']:.2f}')

# 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)
```

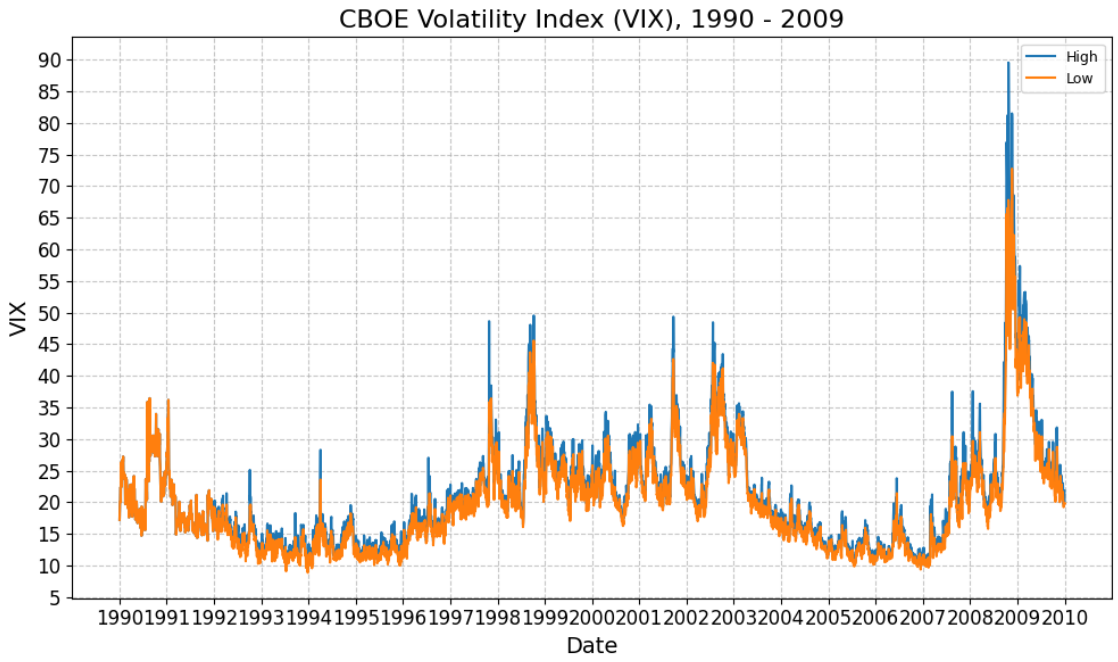
```
# Set Y axis
y_tick_spacing = 25  # Specify the interval for y-axis ticks
plt.gca().yaxis.set_major_locator(MultipleLocator(y_tick_spacing))
plt.ylabel("# Of Datapoints", fontsize=10)
plt.yticks(fontsize=8)

# 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("01_Histogram+Mean+SD.png", dpi=300, bbox_inches="tight")
plt.show()
```



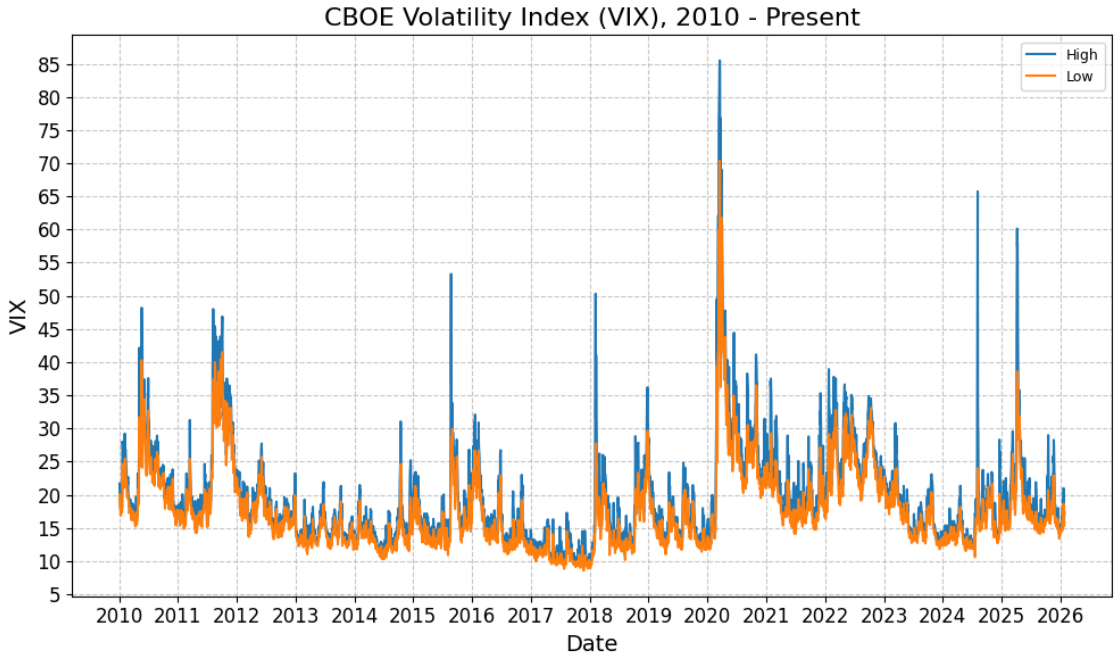
1.7.2 Historical Data - VIX

[33]:
```
plot_timeseries(
    price_df=vix,
    plot_start_date=None,
    plot_end_date="2009-12-31",
    plot_columns=["High", "Low"],
    title="CBOE Volatility Index (VIX), 1990 - 2009",
    x_label="Date",
    x_format="Year",
    y_label="VIX",
    y_format="Decimal",
```

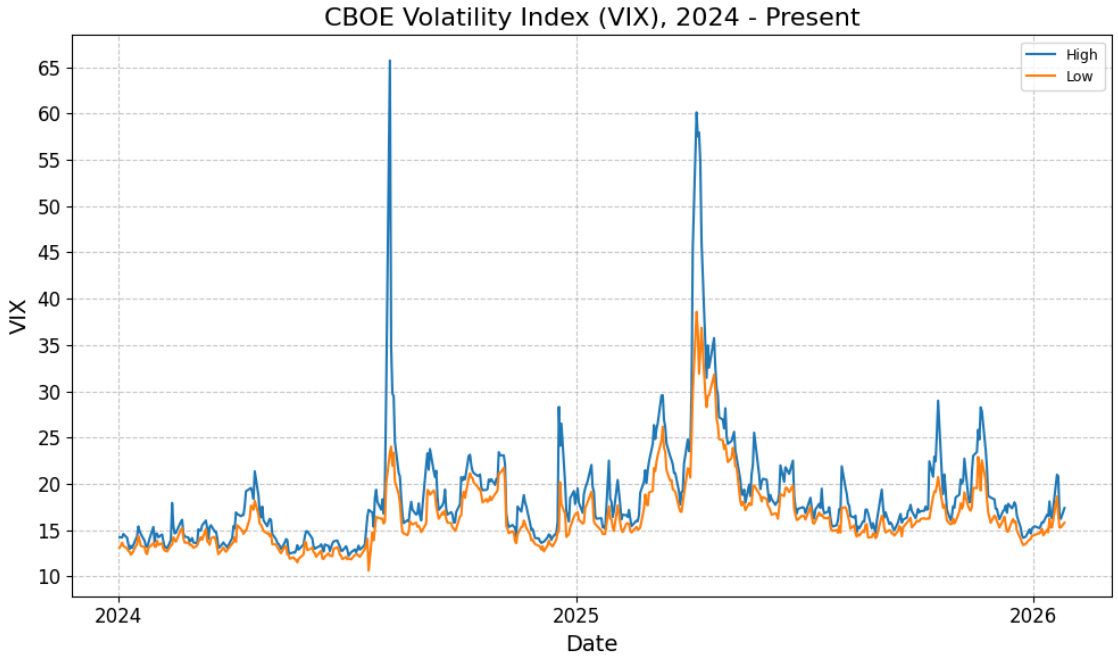
```
    y_format_decimal_places=0,
    y_tick_spacing=5,
    grid=True,
    legend=True,
    export_plot=True,
    plot_file_name="01_VIX_Plot_1990-2009",
)
```



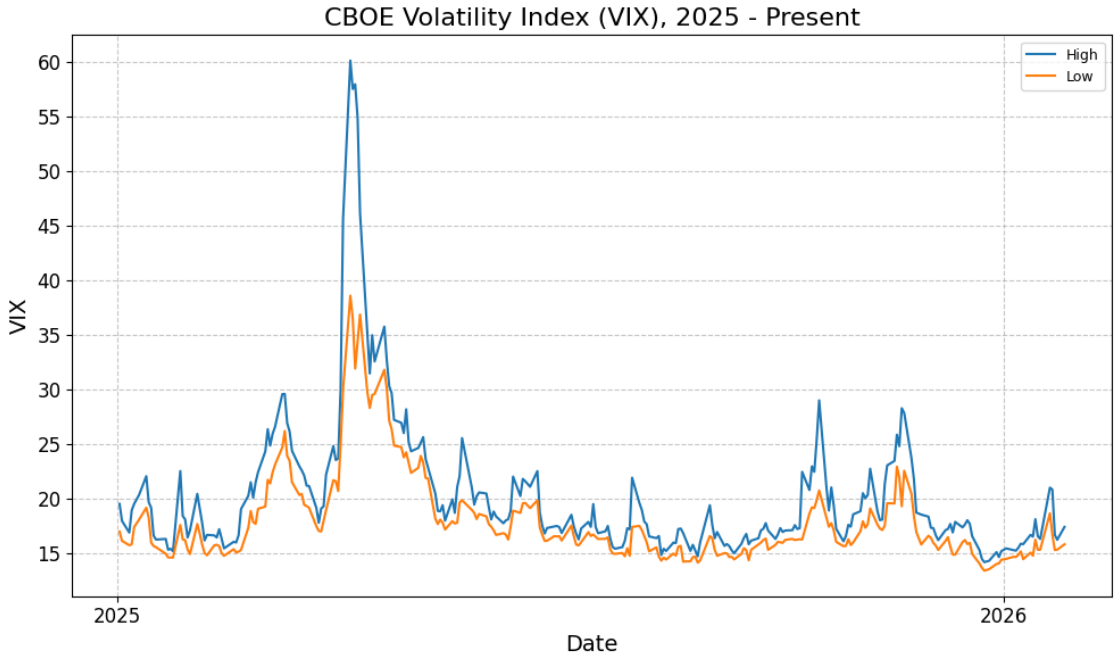
[34]:
```
plot_timeseries(
    price_df=vix,
    plot_start_date="2010-01-01",
    plot_end_date=None,
    plot_columns=["High", "Low"],
    title="CBOE Volatility Index (VIX), 2010 - Present",
    x_label="Date",
    x_format="Year",
    y_label="VIX",
    y_format="Decimal",
    y_format_decimal_places=0,
    y_tick_spacing=5,
    grid=True,
    legend=True,
    export_plot=True,
    plot_file_name="01_VIX_Plot_2010-Present",
)
```



[35]:
```
plot_timeseries(
    price_df=vix,
    plot_start_date="2024-01-01",
    plot_end_date=None,
    plot_columns=["High", "Low"],
    title="CBOE Volatility Index (VIX), 2024 - Present",
    x_label="Date",
    x_format="Year",
    y_label="VIX",
    y_format="Decimal",
    y_format_decimal_places=0,
    y_tick_spacing=5,
    grid=True,
    legend=True,
    export_plot=True,
    plot_file_name="01_VIX_Plot_2024-Present",
)
```

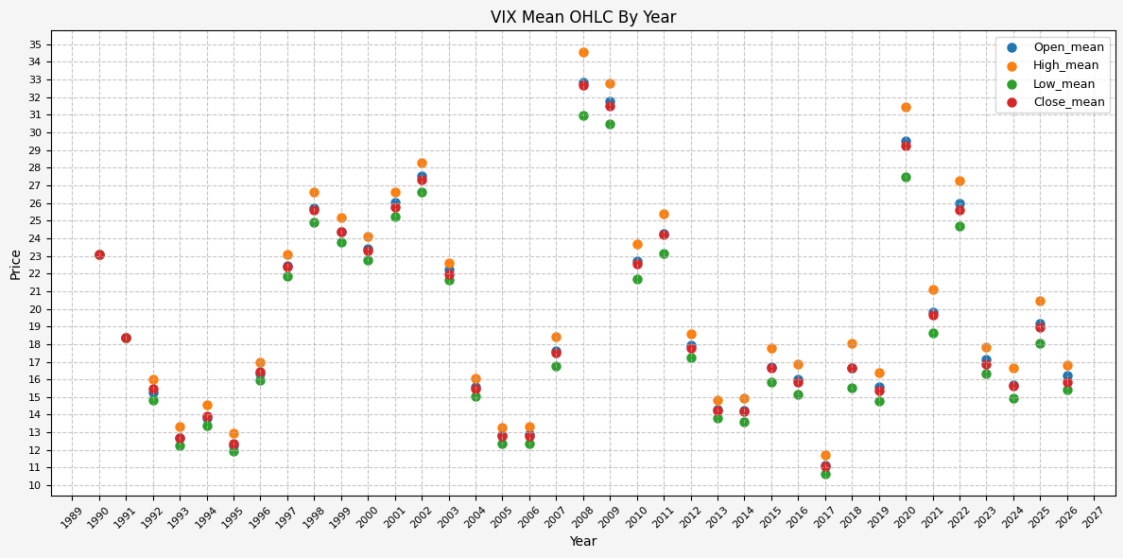


[36]:
```
plot_timeseries(
    price_df=vix,
    plot_start_date="2025-01-01",
    plot_end_date=None,
    plot_columns=["High", "Low"],
    title="CBOE Volatility Index (VIX), 2025 - Present",
    x_label="Date",
    x_format="Year",
    y_label="VIX",
    y_format="Decimal",
    y_format_decimal_places=0,
    y_tick_spacing=5,
    grid=True,
    legend=True,
    export_plot=True,
    plot_file_name="01_VIX_Plot_2025-Present",
)
```



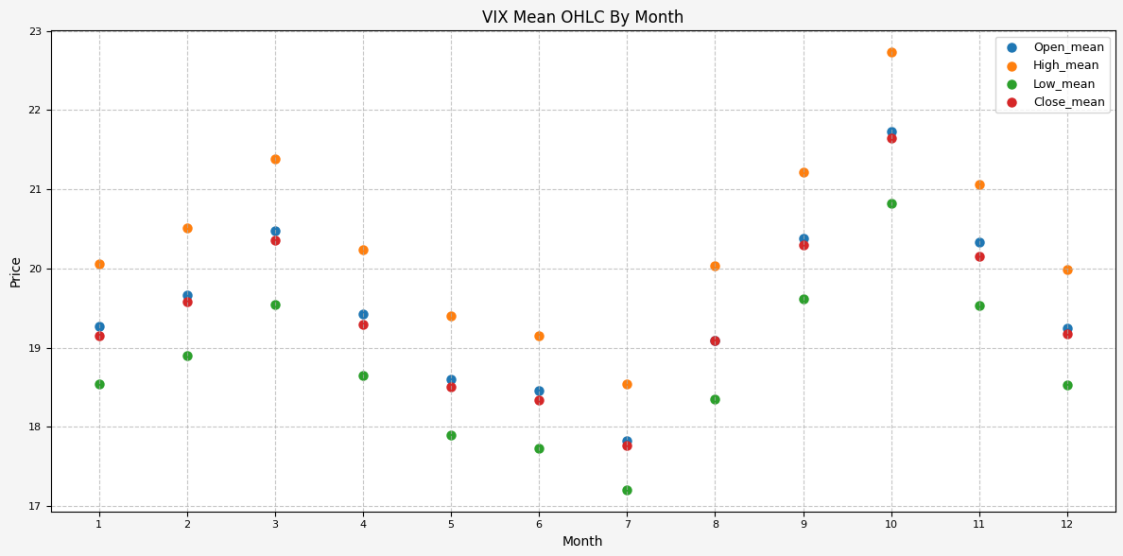
1.7.3 Stats By Year - VIX

[37]:
```
plot_stats(
    stats_df=vix_stats_by_year,
    plot_columns=["Open_mean", "High_mean", "Low_mean", "Close_mean"],
    title="VIX Mean OHLC By Year",
    x_label="Year",
    x_rotation=45,
    x_tick_spacing=1,
    y_label="Price",
    y_tick_spacing=1,
    grid=True,
    legend=True,
    export_plot=True,
    plot_file_name="01_VIX_Stats_By_Year"
)
```



1.7.4 Stats By Month - VIX

[38]:
```
plot_stats(
    stats_df=vix_stats_by_month,
    plot_columns=["Open_mean", "High_mean", "Low_mean", "Close_mean"],
    title="VIX Mean OHLC By Month",
    x_label="Month",
    x_rotation=0,
    x_tick_spacing=1,
    y_label="Price",
    y_tick_spacing=1,
    grid=True,
    legend=True,
    export_plot=True,
    plot_file_name="01_VIX_Stats_By_Month"
)
```



1.8 Data Overview - VVIX

1.8.1 Acquire CBOE VVIX Data

[39]:
```
yf_pull_data(
    base_directory=DATA_DIR,
    ticker="^VVIX",
    source="Yahoo_Finance",
    asset_class="Indices",
    excel_export=True,
    pickle_export=True,
    output_confirmation=True,
)
```

```
[**********100%**********]  1 of 1 completed


The first and last date of data for ^VVIX is:

            Close  High   Low  Open  Volume
Date
2007-01-03  87.63 87.63 87.63 87.63       0

            Close   High   Low   Open  Volume
Date
2026-01-26  99.75 102.62 99.01 102.62       0

Yahoo Finance data complete for ^VVIX
--------------------
```

[39]:

Date	Close	High	Low	Open	Volume
2007-01-03	87.63	87.63	87.63	87.63	0
2007-01-04	88.19	88.19	88.19	88.19	0
2007-01-05	90.17	90.17	90.17	90.17	0
2007-01-08	92.04	92.04	92.04	92.04	0
2007-01-09	92.76	92.76	92.76	92.76	0
…	…	…	…	…	…
2026-01-20	117.05	120.21	110.28	118.27	0
2026-01-21	102.57	113.46	101.47	112.72	0
2026-01-22	96.12	101.96	95.93	100.10	0
2026-01-23	101.83	101.91	96.23	99.03	0
2026-01-26	99.75	102.62	99.01	102.62	0

[4787 rows x 5 columns]

1.8.2 Load Data - VVIX

[40]:
```
# Set decimal places
pandas_set_decimal_places(2)

# VVIX
vvix = load_data(
    base_directory=DATA_DIR,
    ticker="^VVIX",
    source="Yahoo_Finance",
    asset_class="Indices",
    timeframe="Daily",
    file_format="excel",
)

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

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

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

# Check to see if there are any NaN values
vvix[vvix['High'].isna()]

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

1.8.3 DataFrame Info - VVIX

[41]:
```
df_info(vvix)
```

```
The columns, shape, and data types are:
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 4787 entries, 2007-01-03 to 2026-01-26
Data columns (total 4 columns):
 #   Column  Non-Null Count  Dtype
---  ------  --------------  -----
 0   Close   4787 non-null   float64
 1   High    4787 non-null   float64
 2   Low     4787 non-null   float64
 3   Open    4787 non-null   float64
dtypes: float64(4)
memory usage: 187.0 KB
None
The first 5 rows are:

            Close  High   Low  Open
Date
2007-01-03  87.63 87.63 87.63 87.63
2007-01-04  88.19 88.19 88.19 88.19
2007-01-05  90.17 90.17 90.17 90.17
2007-01-08  92.04 92.04 92.04 92.04
2007-01-09  92.76 92.76 92.76 92.76

The last 5 rows are:

            Close   High    Low   Open
Date
2026-01-20 117.05 120.21 110.28 118.27
2026-01-21 102.57 113.46 101.47 112.72
2026-01-22  96.12 101.96  95.93 100.10
2026-01-23 101.83 101.91  96.23  99.03
2026-01-26  99.75 102.62  99.01 102.62
```

[42]:
```
# Copy this <!-- INSERT_02_VVIX_DF_Info_HERE --> to index_temp.md
export_track_md_deps(
    dep_file=dep_file,
    md_filename="02_VVIX_DF_Info.md",
    content=df_info_markdown(vix),
    output_type="markdown",
)
```

```
 Exported and tracked: 02_VVIX_DF_Info.md
```

1.8.4 Statistics - VVIX

[43]:
```
vvix_stats = vvix.describe()
num_std = [-1, 0, 1, 2, 3, 4, 5]
for num in num_std:
    vvix_stats.loc[f"mean + {num} std"] = {
        'Open': vvix_stats.loc['mean']['Open'] + num * vvix_stats.
 ↪loc['std']['Open'],
        'High': vvix_stats.loc['mean']['High'] + num * vvix_stats.
 ↪loc['std']['High'],
        'Low': vvix_stats.loc['mean']['Low'] + num * vvix_stats.
 ↪loc['std']['Low'],
        'Close': vvix_stats.loc['mean']['Close'] + num * vvix_stats.
 ↪loc['std']['Close'],
    }
display(vvix_stats)
```

	Close	High	Low	Open
count	4787.00	4787.00	4787.00	4787.00
mean	93.66	95.76	92.07	93.91
std	16.26	17.89	14.91	16.31
min	59.74	59.74	59.31	59.31
25%	82.59	83.81	81.69	82.84
50%	90.89	92.70	89.72	91.30
75%	102.13	105.07	99.86	102.58
max	207.59	212.22	187.27	212.22
mean + -1 std	77.40	77.87	77.16	77.60
mean + 0 std	93.66	95.76	92.07	93.91
mean + 1 std	109.92	113.65	106.98	110.23
mean + 2 std	126.18	131.53	121.90	126.54
mean + 3 std	142.44	149.42	136.81	142.85
mean + 4 std	158.70	167.31	151.72	159.17
mean + 5 std	174.96	185.19	166.63	175.48

[44]:
```
# Copy this <!-- INSERT_02_VVIX_Stats_HERE --> to index_temp.md
export_track_md_deps(
    dep_file=dep_file,
    md_filename="02_VVIX_Stats.md",
    content=vvix_stats.to_markdown(floatfmt=".2f"),
    output_type="markdown",
)
```

```
Exported and tracked: 02_VVIX_Stats.md
```

[45]:
```
# Group by year and calculate mean and std for OHLC
vvix_stats_by_year = vvix.groupby(vvix.index.year)[["Open", "High", "Low",␣
 ↪"Close"]].agg(["mean", "std", "min", "max"])
```

```
# Flatten the column MultiIndex
vvix_stats_by_year.columns = ['_'.join(col).strip() for col in␣
 ↪vvix_stats_by_year.columns.values]
vvix_stats_by_year.index.name = "Year"

display(vvix_stats_by_year)
```

Year	Open_mean	Open_std	Open_min	Open_max	High_mean	High_std	High_min
2007	87.68	13.31	63.52	142.99	87.68	13.31	63.52
2008	81.85	15.60	59.74	134.87	81.85	15.60	59.74
2009	79.78	8.63	64.95	104.02	79.78	8.63	64.95
2010	88.36	13.07	64.87	145.12	88.36	13.07	64.87
2011	92.94	10.21	75.94	134.63	92.94	10.21	75.94
2012	94.84	8.38	78.42	117.44	94.84	8.38	78.42
2013	80.52	8.97	62.71	111.43	80.52	8.97	62.71
2014	83.01	14.33	61.76	138.60	83.01	14.33	61.76
2015	95.44	15.59	73.07	212.22	98.47	16.39	76.41
2016	93.36	10.02	77.96	131.95	95.82	10.86	78.86
2017	90.50	8.65	75.09	134.98	92.94	9.64	77.34
2018	102.60	13.22	83.70	176.72	106.27	16.26	85.00
2019	91.28	8.43	75.58	112.75	93.61	8.98	75.95
2020	118.64	19.32	88.39	203.03	121.91	20.88	88.54
2021	115.51	9.37	96.09	151.35	119.29	11.70	98.36
2022	102.58	18.01	76.48	161.09	105.32	19.16	77.93
2023	90.95	8.64	74.43	127.73	93.72	9.98	75.31
2024	92.88	15.06	59.31	169.68	97.32	18.33	74.79
2025	101.94	12.83	83.19	186.33	106.13	15.40	84.54
2026	98.43	8.48	89.81	118.27	100.45	8.70	90.43

Year	High_max	Low_mean	Low_std	Low_min	Low_max	Close_mean	Close_std
2007	142.99	87.68	13.31	63.52	142.99	87.68	13.31
2008	134.87	81.85	15.60	59.74	134.87	81.85	15.60
2009	104.02	79.78	8.63	64.95	104.02	79.78	8.63
2010	145.12	88.36	13.07	64.87	145.12	88.36	13.07
2011	134.63	92.94	10.21	75.94	134.63	92.94	10.21
2012	117.44	94.84	8.38	78.42	117.44	94.84	8.38
2013	111.43	80.52	8.97	62.71	111.43	80.52	8.97
2014	138.60	83.01	14.33	61.76	138.60	83.01	14.33
2015	212.22	92.15	13.35	72.20	148.68	94.82	14.75
2016	132.42	90.54	8.99	76.17	115.15	92.80	10.07
2017	135.32	87.85	7.78	71.75	117.29	90.01	8.80
2018	203.73	99.17	11.31	82.60	165.35	102.26	14.04
2019	117.63	88.90	7.86	74.36	111.48	91.03	8.36
2020	209.76	115.05	17.37	85.31	187.27	118.36	19.39
2021	168.78	111.99	8.14	95.92	144.19	115.32	10.20
2022	172.82	99.17	16.81	76.13	153.26	101.81	17.81

```
2023    137.65     88.01     7.37    72.27   119.64      90.34       8.38
2024    192.49     89.51    13.16    59.31   137.05      92.81      15.60
2025    189.03     98.38    10.11    81.72   146.51     101.32      12.36
2026    120.21     95.34     6.43    86.70   110.28      97.43       7.76
```

Year	Close_min	Close_max
2007	63.52	142.99
2008	59.74	134.87
2009	64.95	104.02
2010	64.87	145.12
2011	75.94	134.63
2012	78.42	117.44
2013	62.71	111.43
2014	61.76	138.60
2015	73.18	168.75
2016	76.17	125.13
2017	75.64	135.32
2018	83.21	180.61
2019	74.98	114.40
2020	86.87	207.59
2021	97.09	157.69
2022	77.05	154.38
2023	73.88	124.75
2024	73.26	173.32
2025	81.89	170.92
2026	88.19	117.05

[46]:
```
# Copy this <!-- INSERT_02_VVIX_Stats_By_Year_HERE --> to index_temp.md
export_track_md_deps(
    dep_file=dep_file,
    md_filename="02_VVIX_Stats_By_Year.md",
    content=vvix_stats_by_year.to_markdown(floatfmt=".2f"),
    output_type="markdown",
)
```

```
Exported and tracked: 02_VVIX_Stats_By_Year.md
```

[47]:
```
# Group by month and calculate mean and std for OHLC
vvix_stats_by_month = vvix.groupby(vvix.index.month)[["Open", "High", "Low",␣
 ↪"Close"]].agg(["mean", "std", "min", "max"])

# Flatten the column MultiIndex
vvix_stats_by_month.columns = ['_'.join(col).strip() for col in␣
 ↪vvix_stats_by_month.columns.values]
vvix_stats_by_month.index.name = "Year"

display(vvix_stats_by_month)
```

```
      Open_mean  Open_std  Open_min  Open_max  High_mean  High_std  High_min  \
Year
1         92.70     15.45     64.87    161.09      94.62     17.39     64.87
2         93.49     18.24     65.47    176.72      95.39     20.70     65.47
3         95.30     21.66     66.97    203.03      97.38     23.56     66.97
4         92.18     19.03     59.74    186.33      94.01     20.57     59.74
5         92.25     16.93     61.76    145.18      93.95     17.99     61.76
6         93.16     14.86     63.52    155.48      94.76     16.11     63.52
7         90.10     12.82     67.21    138.42      91.63     13.88     67.21
8         96.84     16.53     68.05    212.22      98.99     18.33     68.05
9         94.91     13.70     67.94    135.17      96.84     15.36     67.94
10        98.05     13.86     64.97    149.60      99.88     15.05     64.97
11        94.24     14.31     63.77    142.68      95.93     15.64     63.77
12        93.32     14.67     59.31    151.35      95.31     16.24     62.71

      High_max  Low_mean  Low_std  Low_min  Low_max  Close_mean  Close_std  \
Year
1       172.82     90.87    14.03    64.87   153.26       92.44      15.56
2       203.73     91.39    16.43    65.47   165.35       93.13      18.58
3       209.76     92.94    19.51    66.97   187.27       94.89      21.59
4       189.03     90.30    17.21    59.74   152.01       91.88      18.60
5       151.50     90.54    16.14    61.76   145.12       91.79      16.79
6       172.21     91.49    13.79    63.52   140.15       92.98      14.83
7       149.60     88.60    11.94    67.21   133.82       89.98      12.78
8       212.22     94.67    14.50    68.05   148.68       96.61      16.24
9       147.14     93.04    12.20    67.94   128.46       94.58      13.44
10      154.99     96.36    13.11    64.97   144.55       97.87      14.02
11      161.76     92.55    13.40    63.77   140.44       93.95      14.37
12      168.37     91.71    13.37    59.31   144.19       93.38      14.72

      Close_min  Close_max
Year
1         64.87     157.69
2         65.47     180.61
3         66.97     207.59
4         59.74     170.92
5         61.76     146.28
6         63.52     151.60
7         67.21     139.54
8         68.05     173.32
9         67.94     138.93
10        64.97     152.01
11        63.77     149.74
12        62.71     156.10
```

[48]:
```
# Copy this <!-- INSERT_02_VVIX_Stats_By_Month_HERE --> to index_temp.md
export_track_md_deps(
```

```
    dep_file=dep_file,
    md_filename="02_VVIX_Stats_By_Month.md",
    content=vvix_stats_by_month.to_markdown(floatfmt=".2f"),
    output_type="markdown",
)
```

```
Exported and tracked: 02_VVIX_Stats_By_Month.md
```

1.8.5 Deciles - VVIX

[49]:
```
vvix_deciles = vvix.quantile(np.arange(0, 1.1, 0.1))
display(vvix_deciles)
```

	Close	High	Low	Open
0.00	59.74	59.74	59.31	59.31
0.10	76.05	76.41	75.59	76.14
0.20	80.83	81.67	80.03	80.99
0.30	84.19	85.58	83.31	84.50
0.40	87.54	88.97	86.39	87.81
0.50	90.89	92.70	89.72	91.30
0.60	94.49	96.66	93.28	94.81
0.70	99.18	101.75	97.47	99.48
0.80	105.84	109.38	103.68	106.43
0.90	115.10	118.68	112.33	115.28
1.00	207.59	212.22	187.27	212.22

[50]:
```
# Copy this <!-- INSERT_02_VVIX_Deciles_HERE --> to index_temp.md
export_track_md_deps(
    dep_file=dep_file,
    md_filename="02_VVIX_Deciles.md",
    content=vvix_deciles.to_markdown(floatfmt=".2f"),
    output_type="markdown",
)
```

```
Exported and tracked: 02_VVIX_Deciles.md
```

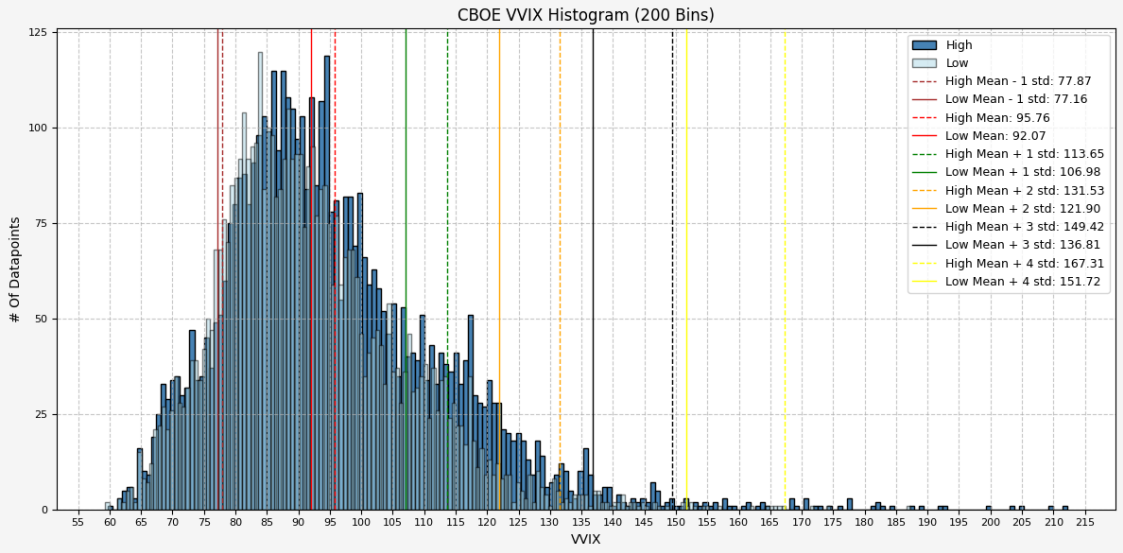
1.9 Plots - VVIX

1.9.1 Histogram Distribution - VVIX

[51]:
```
# Plotting
plt.figure(figsize=(12, 6), facecolor="#F5F5F5")

# Histogram
plt.hist([vvix['High']], label=['High'], bins=200, edgecolor='black',␣
 ↪color='steelblue', alpha=1)
plt.hist([vvix['Low']], label=['Low'], bins=200, edgecolor='black',␣
 ↪color='lightblue', alpha=0.5)
```

```
# Plot a vertical line at the mean, mean + 1 std, and mean + 2 std
plt.axvline(vvix_stats.loc['mean + -1 std']['High'], color='brown',␣
 ↪linestyle='dashed', linewidth=1, label=f'High Mean - 1 std: {vvix_stats.
 ↪loc['mean + -1 std']['High']:.2f}')
plt.axvline(vvix_stats.loc['mean + -1 std']['Low'], color='brown',␣
 ↪linestyle='solid', linewidth=1, label=f'Low Mean - 1 std: {vvix_stats.
 ↪loc['mean + -1 std']['Low']:.2f}')

plt.axvline(vvix_stats.loc['mean']['High'], color='red', linestyle='dashed',␣
 ↪linewidth=1, label=f'High Mean: {vvix_stats.loc['mean']['High']:.2f}')
plt.axvline(vvix_stats.loc['mean']['Low'], color='red', linestyle='solid',␣
 ↪linewidth=1, label=f'Low Mean: {vvix_stats.loc['mean']['Low']:.2f}')

plt.axvline(vvix_stats.loc['mean + 1 std']['High'], color='green',␣
 ↪linestyle='dashed', linewidth=1, label=f'High Mean + 1 std: {vvix_stats.
 ↪loc['mean + 1 std']['High']:.2f}')
plt.axvline(vvix_stats.loc['mean + 1 std']['Low'], color='green',␣
 ↪linestyle='solid', linewidth=1, label=f'Low Mean + 1 std: {vvix_stats.
 ↪loc['mean + 1 std']['Low']:.2f}')

plt.axvline(vvix_stats.loc['mean + 2 std']['High'], color='orange',␣
 ↪linestyle='dashed', linewidth=1, label=f'High Mean + 2 std: {vvix_stats.
 ↪loc['mean + 2 std']['High']:.2f}')
plt.axvline(vvix_stats.loc['mean + 2 std']['Low'], color='orange',␣
 ↪linestyle='solid', linewidth=1, label=f'Low Mean + 2 std: {vvix_stats.
 ↪loc['mean + 2 std']['Low']:.2f}')

plt.axvline(vvix_stats.loc['mean + 3 std']['High'], color='black',␣
 ↪linestyle='dashed', linewidth=1, label=f'High Mean + 3 std: {vvix_stats.
 ↪loc['mean + 3 std']['High']:.2f}')
plt.axvline(vvix_stats.loc['mean + 3 std']['Low'], color='black',␣
 ↪linestyle='solid', linewidth=1, label=f'Low Mean + 3 std: {vvix_stats.
 ↪loc['mean + 3 std']['Low']:.2f}')

plt.axvline(vvix_stats.loc['mean + 4 std']['High'], color='yellow',␣
 ↪linestyle='dashed', linewidth=1, label=f'High Mean + 4 std: {vvix_stats.
 ↪loc['mean + 4 std']['High']:.2f}')
plt.axvline(vvix_stats.loc['mean + 4 std']['Low'], color='yellow',␣
 ↪linestyle='solid', linewidth=1, label=f'Low Mean + 4 std: {vvix_stats.
 ↪loc['mean + 4 std']['Low']:.2f}')

# 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("VVIX", fontsize=10)
plt.xticks(rotation=0, fontsize=8)
```

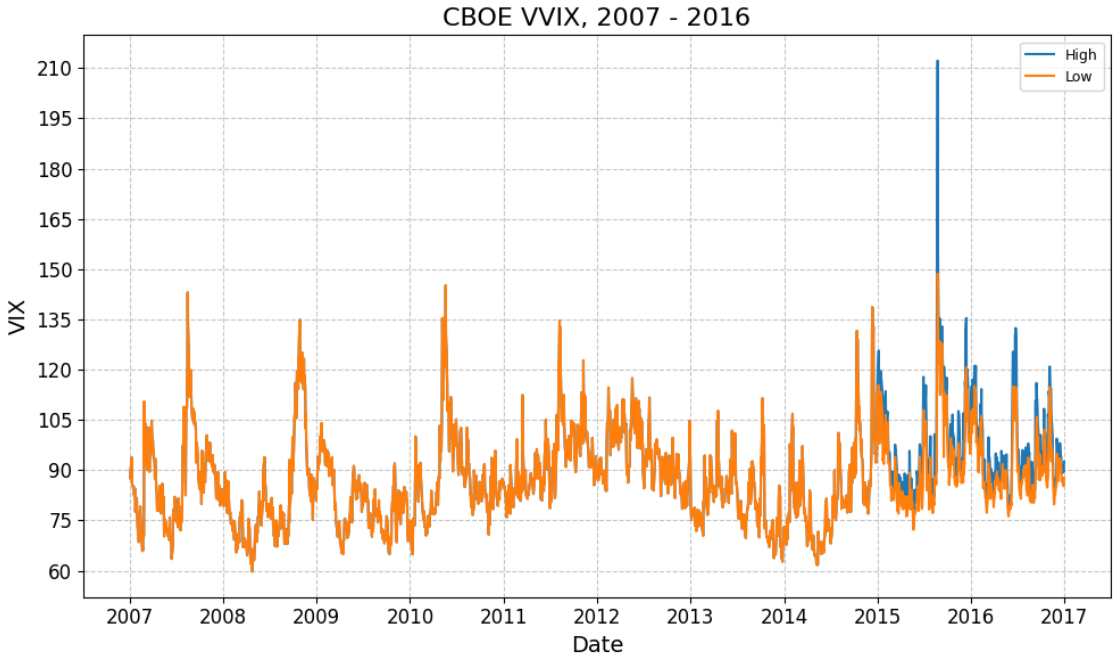
```
# Set Y axis
y_tick_spacing = 25  # Specify the interval for y-axis ticks
plt.gca().yaxis.set_major_locator(MultipleLocator(y_tick_spacing))
plt.ylabel("# Of Datapoints", fontsize=10)
plt.yticks(fontsize=8)

# Set title, layout, grid, and legend
plt.title("CBOE VVIX 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("02_Histogram+Mean+SD.png", dpi=300, bbox_inches="tight")
plt.show()
```



1.9.2 Historical Data - VVIX

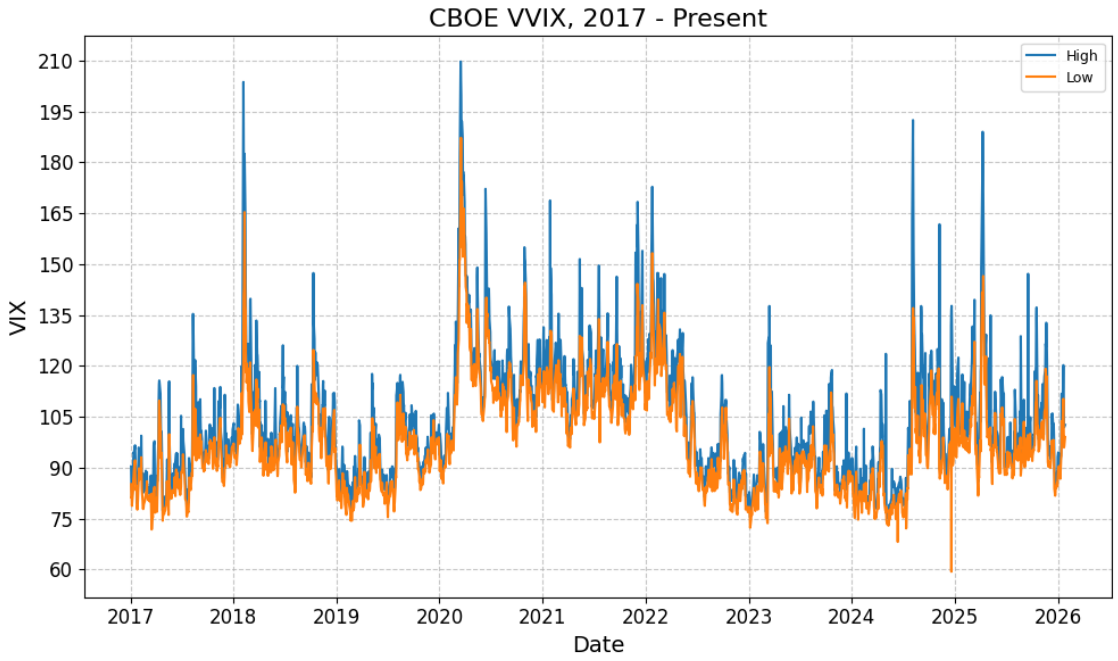
[52]:
```
plot_timeseries(
    price_df=vvix,
    plot_start_date=None,
    plot_end_date="2016-12-31",
    plot_columns=["High", "Low"],
    title="CBOE VVIX, 2007 - 2016",
    x_label="Date",
    x_format="Year",
    y_label="VIX",
```

```
    y_format="Decimal",
    y_format_decimal_places=0,
    y_tick_spacing=15,
    grid=True,
    legend=True,
    export_plot=True,
    plot_file_name="02_VVIX_Plot_2007-2016",
)
```

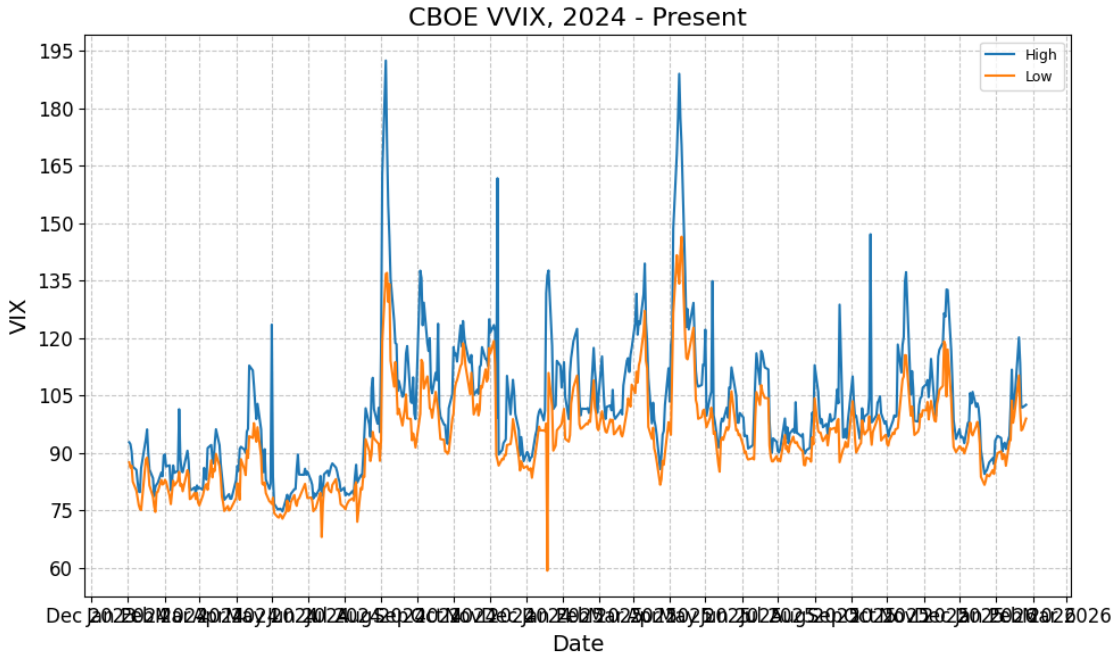


[53]:
```
plot_timeseries(
    price_df=vvix,
    plot_start_date="2017-01-01",
    plot_end_date=None,
    plot_columns=["High", "Low"],
    title="CBOE VVIX, 2017 - Present",
    x_label="Date",
    x_format="Year",
    y_label="VIX",
    y_format="Decimal",
    y_format_decimal_places=0,
    y_tick_spacing=15,
    grid=True,
    legend=True,
    export_plot=True,
    plot_file_name="02_VVIX_Plot_2017-Present",
```

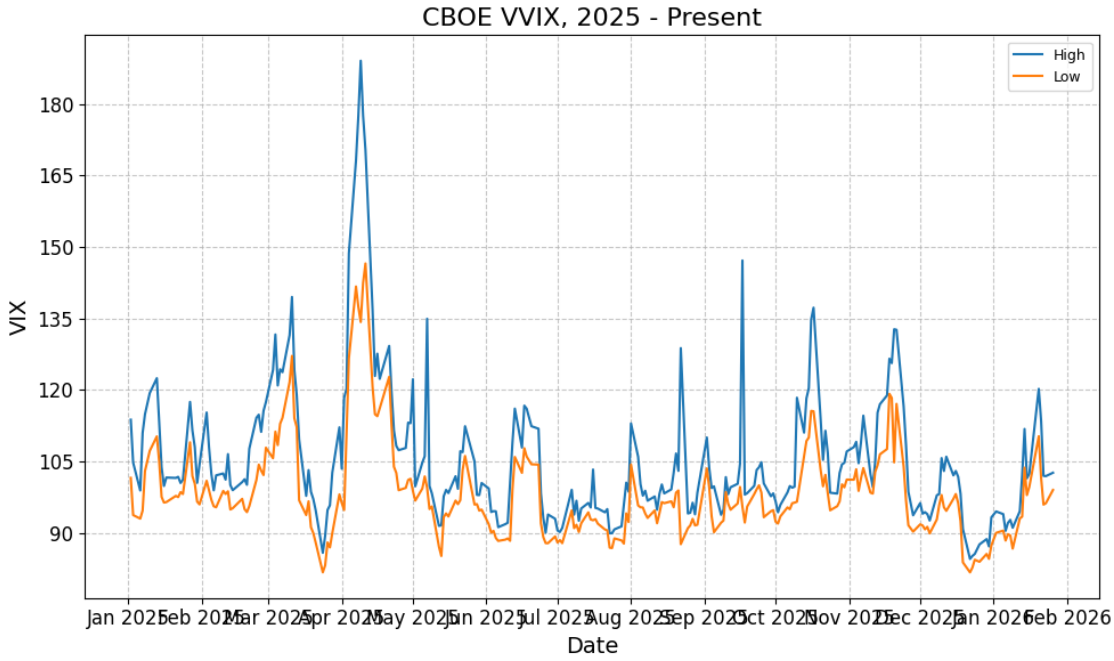
```
)
```



[54]:
```
plot_timeseries(
    price_df=vvix,
    plot_start_date="2024-01-01",
    plot_end_date=None,
    plot_columns=["High", "Low"],
    title="CBOE VVIX, 2024 - Present",
    x_label="Date",
    x_format="Month",
    y_label="VIX",
    y_format="Decimal",
    y_format_decimal_places=0,
    y_tick_spacing=15,
    grid=True,
    legend=True,
    export_plot=True,
    plot_file_name="02_VVIX_Plot_2024-Present",
)
```

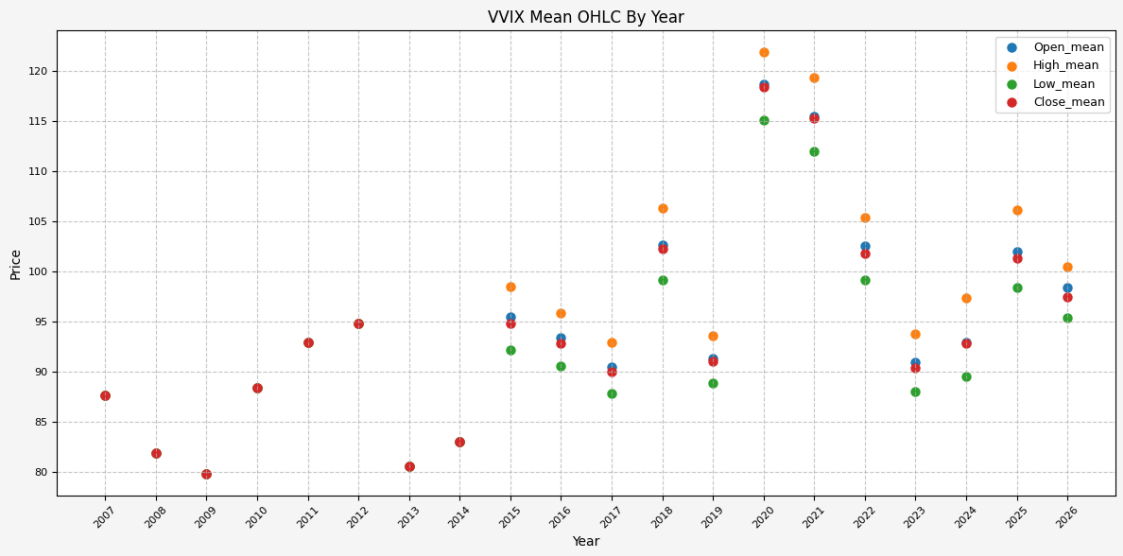


[55]:
```
plot_timeseries(
    price_df=vvix,
    plot_start_date="2025-01-01",
    plot_end_date=None,
    plot_columns=["High", "Low"],
    title="CBOE VVIX, 2025 - Present",
    x_label="Date",
    x_format="Month",
    y_label="VIX",
    y_format="Decimal",
    y_format_decimal_places=0,
    y_tick_spacing=15,
    grid=True,
    legend=True,
    export_plot=True,
    plot_file_name="02_VVIX_Plot_2025-Present",
)
```



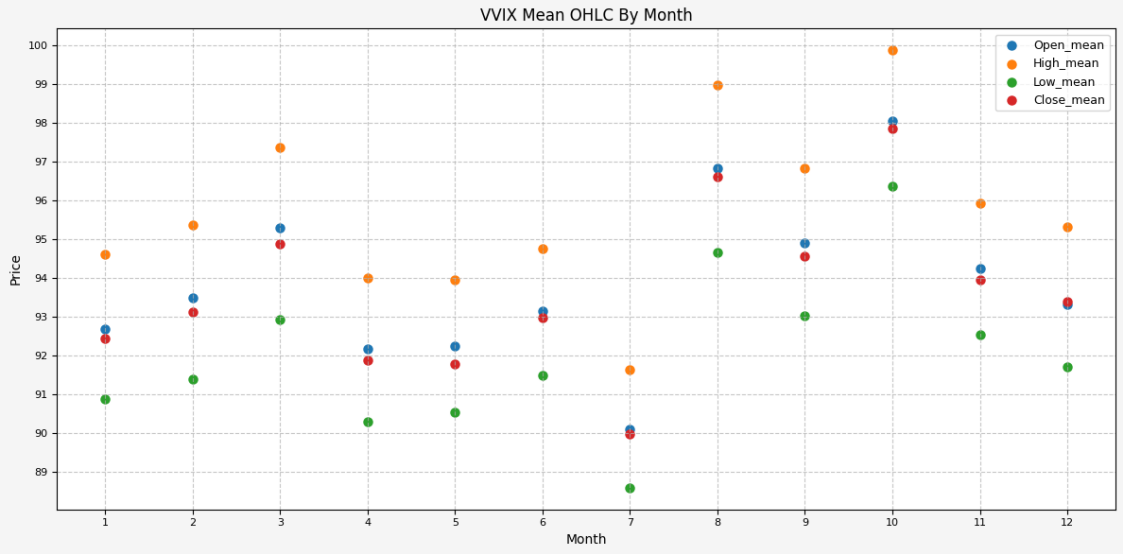
1.9.3 Stats By Year - VVIX

[56]:
```
plot_stats(
    stats_df=vvix_stats_by_year,
    plot_columns=["Open_mean", "High_mean", "Low_mean", "Close_mean"],
    title="VVIX Mean OHLC By Year",
    x_label="Year",
    x_rotation=45,
    x_tick_spacing=1,
    y_label="Price",
    y_tick_spacing=5,
    grid=True,
    legend=True,
    export_plot=True,
    plot_file_name="02_VVIX_Stats_By_Year"
)
```



1.9.4 Stats By Month - VVIX

[57]:
```
plot_stats(
    stats_df=vvix_stats_by_month,
    plot_columns=["Open_mean", "High_mean", "Low_mean", "Close_mean"],
    title="VVIX Mean OHLC By Month",
    x_label="Month",
    x_rotation=0,
    x_tick_spacing=1,
    y_label="Price",
    y_tick_spacing=1,
    grid=True,
    legend=True,
    export_plot=True,
    plot_file_name="02_VVIX_Stats_By_Month"
)
```



1.10 Data Overview - VIX/VVIX

1.10.1 Merge VIX & VVIX Data

[58]:
```
# Merge VIX and VVIX dataframes on Date
vix_over_vvix = pd.merge(vix, vvix, left_index=True, right_index=True,␣
 ↪suffixes=('_VIX', '_VVIX'))

# Calc VIX/VVIX ratios
vix_over_vvix['Close_VIX_to_VVIX_Ratio'] = vix_over_vvix['Close_VIX'] /␣
 ↪vix_over_vvix['Close_VVIX']
vix_over_vvix['High_VIX_to_VVIX_Ratio'] = vix_over_vvix['High_VIX'] /␣
 ↪vix_over_vvix['High_VVIX']
vix_over_vvix['Low_VIX_to_VVIX_Ratio'] = vix_over_vvix['Low_VIX'] /␣
 ↪vix_over_vvix['Low_VVIX']
vix_over_vvix['Open_VIX_to_VVIX_Ratio'] = vix_over_vvix['Open_VIX'] /␣
 ↪vix_over_vvix['Open_VVIX']

# Drop VIX and VVIX columns, keep only ratio columns
vix_over_vvix = vix_over_vvix[['Close_VIX_to_VVIX_Ratio',␣
 ↪'High_VIX_to_VVIX_Ratio', 'Low_VIX_to_VVIX_Ratio', 'Open_VIX_to_VVIX_Ratio']]
```

[59]:
```
df_info(vix_over_vvix)
```

```
The columns, shape, and data types are:
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 4787 entries, 2007-01-03 to 2026-01-26
Data columns (total 4 columns):
 #   Column                    Non-Null Count  Dtype
```

```
---  ------                    --------------  -----
 0   Close_VIX_to_VVIX_Ratio   4787 non-null   float64
 1   High_VIX_to_VVIX_Ratio    4787 non-null   float64
 2   Low_VIX_to_VVIX_Ratio     4787 non-null   float64
 3   Open_VIX_to_VVIX_Ratio    4787 non-null   float64
dtypes: float64(4)
memory usage: 187.0 KB
None
The first 5 rows are:
            Close_VIX_to_VVIX_Ratio  High_VIX_to_VVIX_Ratio  \
Date
2007-01-03                     0.14                    0.15
2007-01-04                     0.13                    0.14
2007-01-05                     0.13                    0.14
2007-01-08                     0.13                    0.14
2007-01-09                     0.13                    0.13

            Low_VIX_to_VVIX_Ratio  Open_VIX_to_VVIX_Ratio
Date
2007-01-03                   0.13                    0.14
2007-01-04                   0.13                    0.14
2007-01-05                   0.13                    0.13
2007-01-08                   0.13                    0.14
2007-01-09                   0.13                    0.13

The last 5 rows are:
            Close_VIX_to_VVIX_Ratio  High_VIX_to_VVIX_Ratio  \
Date
2026-01-20                     0.17                    0.17
2026-01-21                     0.16                    0.18
2026-01-22                     0.16                    0.16
2026-01-23                     0.16                    0.16
2026-01-26                     0.16                    0.17

            Low_VIX_to_VVIX_Ratio  Open_VIX_to_VVIX_Ratio
Date
2026-01-20                   0.17                    0.17
2026-01-21                   0.16                    0.17
2026-01-22                   0.16                    0.17
2026-01-23                   0.16                    0.16
2026-01-26                   0.16                    0.16
```

[60]:
```
# Copy this <!-- INSERT_03_VIX_Over_VVIX_DF_Info_HERE --> to index_temp.md
export_track_md_deps(
    dep_file=dep_file,
    md_filename="03_VIX_Over_VVIX_DF_Info.md",
    content=df_info_markdown(vix_over_vvix),
```

```
    output_type="markdown",
)
```

```
Exported and tracked: 03_VIX_Over_VVIX_DF_Info.md
```

1.10.2 Statistics - VIX/VVIX

[61]:
```
vix_over_vvix_stats = vix_over_vvix.describe()
num_std = [-1, 0, 1, 2, 3, 4, 5]
for num in num_std:
    vix_over_vvix_stats.loc[f"mean + {num} std"] = {
        'Open_VIX_to_VVIX_Ratio': vix_over_vvix_stats.
 ↪loc['mean']['Open_VIX_to_VVIX_Ratio'] + num * vix_over_vvix_stats.
 ↪loc['std']['Open_VIX_to_VVIX_Ratio'],
        'High_VIX_to_VVIX_Ratio': vix_over_vvix_stats.
 ↪loc['mean']['High_VIX_to_VVIX_Ratio'] + num * vix_over_vvix_stats.
 ↪loc['std']['High_VIX_to_VVIX_Ratio'],
        'Low_VIX_to_VVIX_Ratio': vix_over_vvix_stats.
 ↪loc['mean']['Low_VIX_to_VVIX_Ratio'] + num * vix_over_vvix_stats.
 ↪loc['std']['Low_VIX_to_VVIX_Ratio'],
        'Close_VIX_to_VVIX_Ratio': vix_over_vvix_stats.
 ↪loc['mean']['Close_VIX_to_VVIX_Ratio'] + num * vix_over_vvix_stats.
 ↪loc['std']['Close_VIX_to_VVIX_Ratio'],
    }

display(vix_over_vvix_stats)
```

```
              Close_VIX_to_VVIX_Ratio  High_VIX_to_VVIX_Ratio  \
count                         4787.00                 4787.00
mean                             0.21                    0.22
std                              0.09                    0.09
min                              0.10                    0.10
25%                              0.16                    0.16
50%                              0.18                    0.19
75%                              0.24                    0.25
max                              0.76                    0.81
mean + -1 std                    0.13                    0.13
mean + 0 std                     0.21                    0.22
mean + 1 std                     0.30                    0.31
mean + 2 std                     0.38                    0.40
mean + 3 std                     0.47                    0.50
mean + 4 std                     0.56                    0.59
mean + 5 std                     0.64                    0.68

              Low_VIX_to_VVIX_Ratio  Open_VIX_to_VVIX_Ratio
count                       4787.00                 4787.00
mean                           0.21                    0.21
std                            0.08                    0.09
```

min	0.10	0.10
25%	0.16	0.16
50%	0.18	0.19
75%	0.23	0.24
max	0.72	0.81
mean + -1 std	0.12	0.13
mean + 0 std	0.21	0.21
mean + 1 std	0.29	0.30
mean + 2 std	0.37	0.39
mean + 3 std	0.45	0.48
mean + 4 std	0.53	0.56
mean + 5 std	0.62	0.65

[62]:
```
# Copy this <!-- INSERT_03_VIX_Over_VVIX_Stats_HERE --> to index_temp.md
export_track_md_deps(
    dep_file=dep_file,
    md_filename="03_VIX_Over_VVIX_Stats.md",
    content=vix_over_vvix_stats.to_markdown(floatfmt=".2f"),
    output_type="markdown",
)
```

```
Exported and tracked: 03_VIX_Over_VVIX_Stats.md
```

[63]:
```
# # Group by year and calculate mean and std for OHLC
# vvix_stats_by_year = vvix.groupby(vvix.index.year)[["Open", "High", "Low",␣
 ↪"Close"]].agg(["mean", "std", "min", "max"])

# # Flatten the column MultiIndex
# vvix_stats_by_year.columns = ['_'.join(col).strip() for col in␣
 ↪vvix_stats_by_year.columns.values]
# vvix_stats_by_year.index.name = "Year"

# display(vvix_stats_by_year)
```

[64]:
```
# # Copy this <!-- INSERT_02_VVIX_Stats_By_Year_HERE --> to index_temp.md
# export_track_md_deps(dep_file=dep_file, md_filename="02_VVIX_Stats_By_Year.
 ↪md", content=vvix_stats_by_year.to_markdown(floatfmt=".2f"))
```

[65]:
```
# # Group by month and calculate mean and std for OHLC
# vvix_stats_by_month = vvix.groupby(vvix.index.month)[["Open", "High", "Low",␣
 ↪"Close"]].agg(["mean", "std", "min", "max"])

# # Flatten the column MultiIndex
# vvix_stats_by_month.columns = ['_'.join(col).strip() for col in␣
 ↪vvix_stats_by_month.columns.values]
# vvix_stats_by_month.index.name = "Year"

# display(vvix_stats_by_month)
```

[66]:
```
# # Copy this <!-- INSERT_02_VVIX_Stats_By_Month_HERE --> to index_temp.md
# export_track_md_deps(dep_file=dep_file, md_filename="02_VVIX_Stats_By_Month.
  ↪md", content=vvix_stats_by_month.to_markdown(floatfmt=".2f"))
```

1.10.3 Deciles - VIX/VVIX

[67]:
```
vix_over_vvix_deciles = vix_over_vvix.quantile(np.arange(0, 1.1, 0.1))
display(vix_over_vvix_deciles)
```

	Close_VIX_to_VVIX_Ratio	High_VIX_to_VVIX_Ratio	Low_VIX_to_VVIX_Ratio	\
0.00	0.10	0.10	0.10	
0.10	0.14	0.15	0.14	
0.20	0.16	0.16	0.15	
0.30	0.16	0.17	0.16	
0.40	0.17	0.18	0.17	
0.50	0.18	0.19	0.18	
0.60	0.20	0.21	0.19	
0.70	0.22	0.23	0.21	
0.80	0.26	0.27	0.25	
0.90	0.32	0.33	0.31	
1.00	0.76	0.81	0.72	

	Open_VIX_to_VVIX_Ratio
0.00	0.10
0.10	0.14
0.20	0.16
0.30	0.17
0.40	0.17
0.50	0.19
0.60	0.20
0.70	0.22
0.80	0.26
0.90	0.32
1.00	0.81

[68]:
```
# Copy this <!-- INSERT_03_VIX_Over_VVIX_Deciles_HERE --> to index_temp.md
export_track_md_deps(dep_file=dep_file, md_filename="03_VIX_Over_VVIX_Deciles.
  ↪md", content=vix_over_vvix_deciles.to_markdown(floatfmt=".2f"))
```

```
Exported and tracked: 03_VIX_Over_VVIX_Deciles.md
```

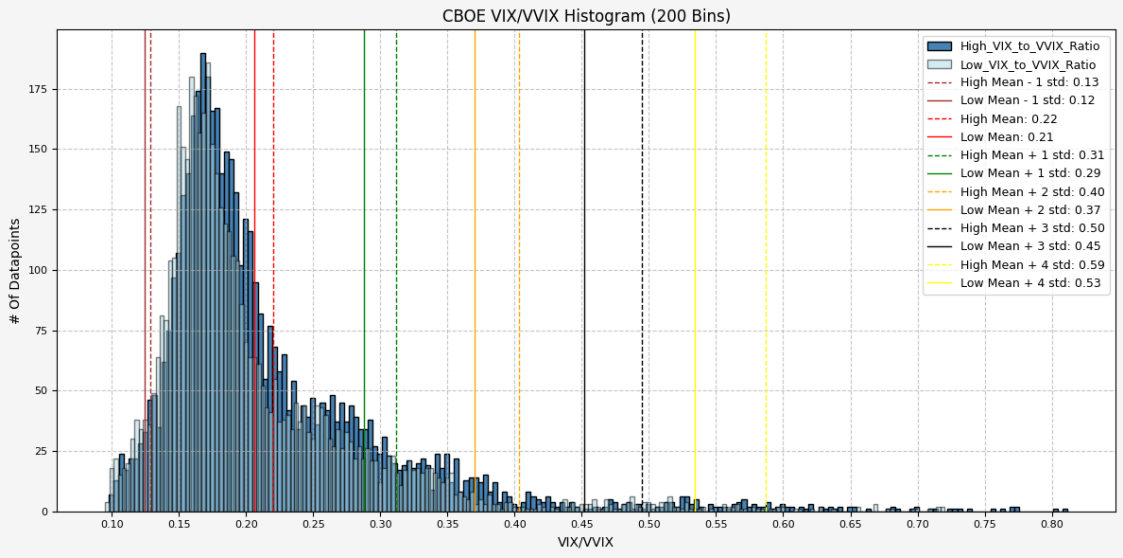
1.11 Plots - VIX/VVIX

1.11.1 Histogram Distribution - VIX/VVIX

[69]:
```
# Plotting
plt.figure(figsize=(12, 6), facecolor="#F5F5F5")
```

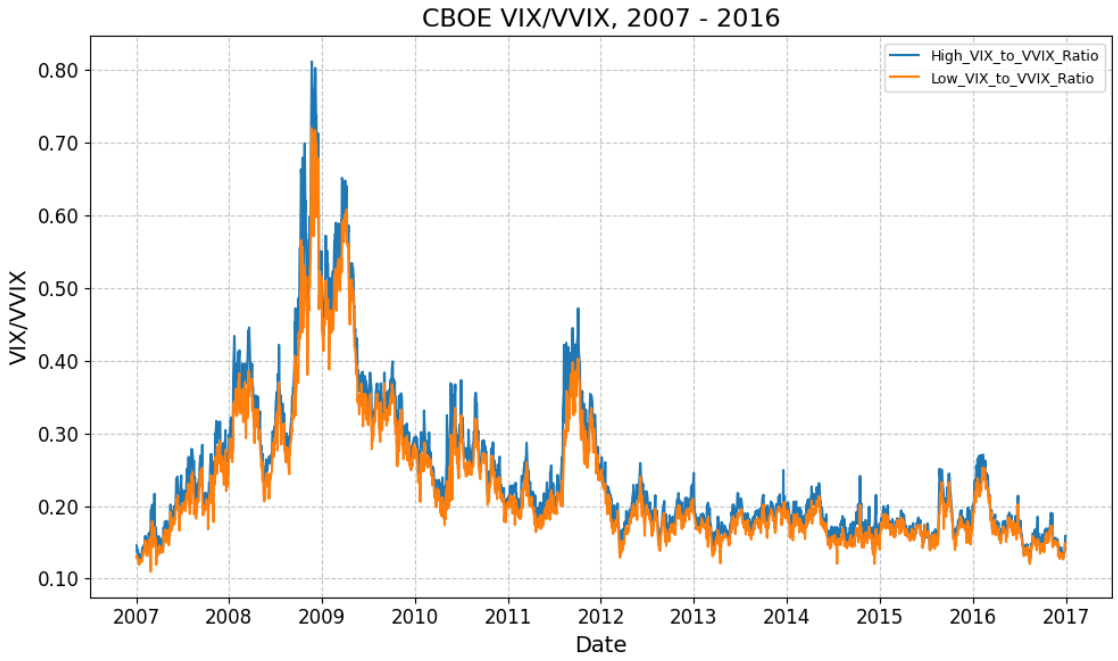
```
# Histogram
plt.hist([vix_over_vvix['High_VIX_to_VVIX_Ratio']],␣
 ↪label=['High_VIX_to_VVIX_Ratio'], bins=200, edgecolor='black',␣
 ↪color='steelblue', alpha=1)
plt.hist([vix_over_vvix['Low_VIX_to_VVIX_Ratio']],␣
 ↪label=['Low_VIX_to_VVIX_Ratio'], bins=200, edgecolor='black',␣
 ↪color='lightblue', alpha=0.5)

# Plot a vertical line at the mean, mean + 1 std, and mean + 2 std
plt.axvline(vix_over_vvix_stats.loc['mean + -1 std']['High_VIX_to_VVIX_Ratio'],␣
 ↪color='brown', linestyle='dashed', linewidth=1, label=f'High Mean - 1 std:␣
 ↪{vix_over_vvix_stats.loc['mean + -1 std']['High_VIX_to_VVIX_Ratio']:.2f}')
plt.axvline(vix_over_vvix_stats.loc['mean + -1 std']['Low_VIX_to_VVIX_Ratio'],␣
 ↪color='brown', linestyle='solid', linewidth=1, label=f'Low Mean - 1 std:␣
 ↪{vix_over_vvix_stats.loc['mean + -1 std']['Low_VIX_to_VVIX_Ratio']:.2f}')

plt.axvline(vix_over_vvix_stats.loc['mean']['High_VIX_to_VVIX_Ratio'],␣
 ↪color='red', linestyle='dashed', linewidth=1, label=f'High Mean:␣
 ↪{vix_over_vvix_stats.loc['mean']['High_VIX_to_VVIX_Ratio']:.2f}')
plt.axvline(vix_over_vvix_stats.loc['mean']['Low_VIX_to_VVIX_Ratio'],␣
 ↪color='red', linestyle='solid', linewidth=1, label=f'Low Mean:␣
 ↪{vix_over_vvix_stats.loc['mean']['Low_VIX_to_VVIX_Ratio']:.2f}')

plt.axvline(vix_over_vvix_stats.loc['mean + 1 std']['High_VIX_to_VVIX_Ratio'],␣
 ↪color='green', linestyle='dashed', linewidth=1, label=f'High Mean + 1 std:␣
 ↪{vix_over_vvix_stats.loc['mean + 1 std']['High_VIX_to_VVIX_Ratio']:.2f}')
plt.axvline(vix_over_vvix_stats.loc['mean + 1 std']['Low_VIX_to_VVIX_Ratio'],␣
 ↪color='green', linestyle='solid', linewidth=1, label=f'Low Mean + 1 std:␣
 ↪{vix_over_vvix_stats.loc['mean + 1 std']['Low_VIX_to_VVIX_Ratio']:.2f}')

plt.axvline(vix_over_vvix_stats.loc['mean + 2 std']['High_VIX_to_VVIX_Ratio'],␣
 ↪color='orange', linestyle='dashed', linewidth=1, label=f'High Mean + 2 std:␣
 ↪{vix_over_vvix_stats.loc['mean + 2 std']['High_VIX_to_VVIX_Ratio']:.2f}')
plt.axvline(vix_over_vvix_stats.loc['mean + 2 std']['Low_VIX_to_VVIX_Ratio'],␣
 ↪color='orange', linestyle='solid', linewidth=1, label=f'Low Mean + 2 std:␣
 ↪{vix_over_vvix_stats.loc['mean + 2 std']['Low_VIX_to_VVIX_Ratio']:.2f}')

plt.axvline(vix_over_vvix_stats.loc['mean + 3 std']['High_VIX_to_VVIX_Ratio'],␣
 ↪color='black', linestyle='dashed', linewidth=1, label=f'High Mean + 3 std:␣
 ↪{vix_over_vvix_stats.loc['mean + 3 std']['High_VIX_to_VVIX_Ratio']:.2f}')
plt.axvline(vix_over_vvix_stats.loc['mean + 3 std']['Low_VIX_to_VVIX_Ratio'],␣
 ↪color='black', linestyle='solid', linewidth=1, label=f'Low Mean + 3 std:␣
 ↪{vix_over_vvix_stats.loc['mean + 3 std']['Low_VIX_to_VVIX_Ratio']:.2f}')
```

```
plt.axvline(vix_over_vvix_stats.loc['mean + 4 std']['High_VIX_to_VVIX_Ratio'],␣
 ↪color='yellow', linestyle='dashed', linewidth=1, label=f'High Mean + 4 std:␣
 ↪{vix_over_vvix_stats.loc['mean + 4 std']['High_VIX_to_VVIX_Ratio']:.2f}')
plt.axvline(vix_over_vvix_stats.loc['mean + 4 std']['Low_VIX_to_VVIX_Ratio'],␣
 ↪color='yellow', linestyle='solid', linewidth=1, label=f'Low Mean + 4 std:␣
 ↪{vix_over_vvix_stats.loc['mean + 4 std']['Low_VIX_to_VVIX_Ratio']:.2f}')

# Set X axis
x_tick_spacing = 0.05  # Specify the interval for y-axis ticks
plt.gca().xaxis.set_major_locator(MultipleLocator(x_tick_spacing))
plt.xlabel("VIX/VVIX", 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 VIX/VVIX 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("03_Histogram+Mean+SD.png", dpi=300, bbox_inches="tight")
plt.show()
```



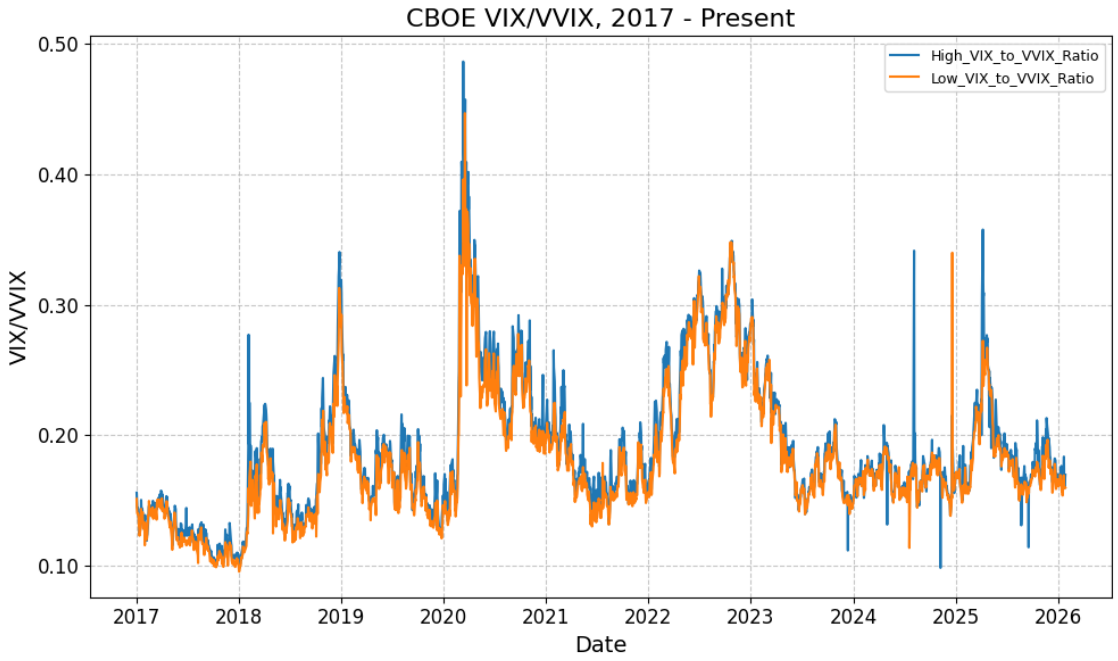
1.11.2 Historical Data - VIX/VVIX

[70]:
```
plot_timeseries(
    price_df=vix_over_vvix,
    plot_start_date=None,
    plot_end_date="2016-12-31",
    plot_columns=["High_VIX_to_VVIX_Ratio", "Low_VIX_to_VVIX_Ratio"],
    title="CBOE VIX/VVIX, 2007 - 2016",
    x_label="Date",
    x_format="Year",
    y_label="VIX/VVIX",
    y_format="Decimal",
    y_format_decimal_places=2,
    y_tick_spacing=0.10,
    grid=True,
    legend=True,
    export_plot=True,
    plot_file_name="03_VIX_Over_VVIX_Plot_2007-2016",
)
```



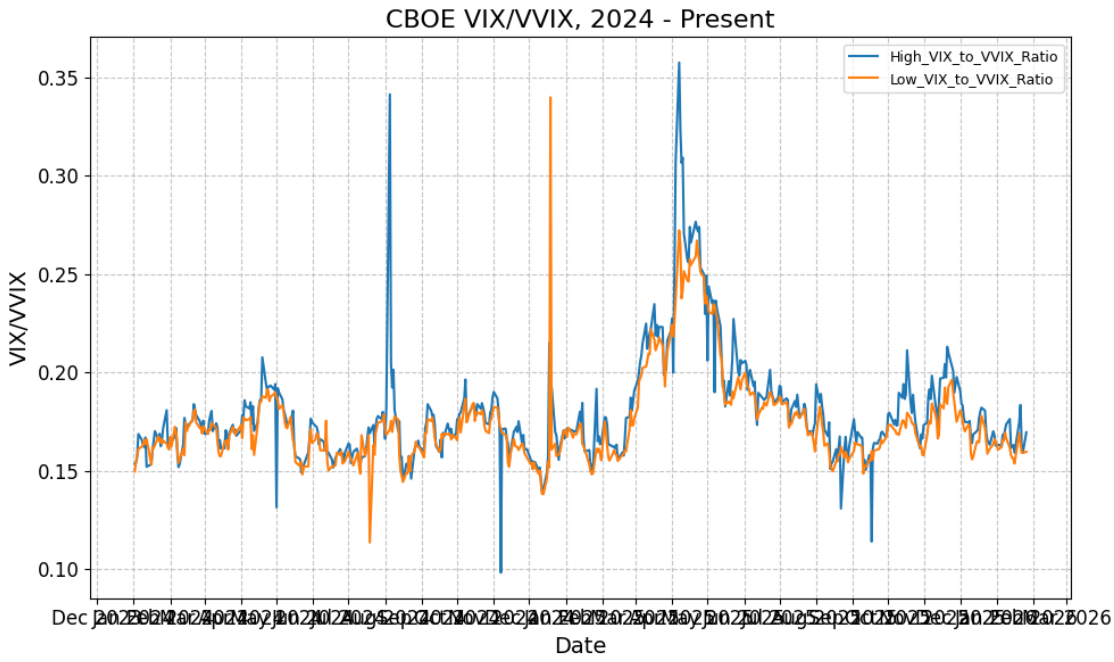
[71]:
```
plot_timeseries(
    price_df=vix_over_vvix,
    plot_start_date="2017-01-01",
    plot_end_date=None,
    plot_columns=["High_VIX_to_VVIX_Ratio", "Low_VIX_to_VVIX_Ratio"],
```

```
    title="CBOE VIX/VVIX, 2017 - Present",
    x_label="Date",
    x_format="Year",
    y_label="VIX/VVIX",
    y_format="Decimal",
    y_format_decimal_places=2,
    y_tick_spacing=0.10,
    grid=True,
    legend=True,
    export_plot=True,
    plot_file_name="03_VIX_Over_VVIX_Plot_2017-Present",
)
```

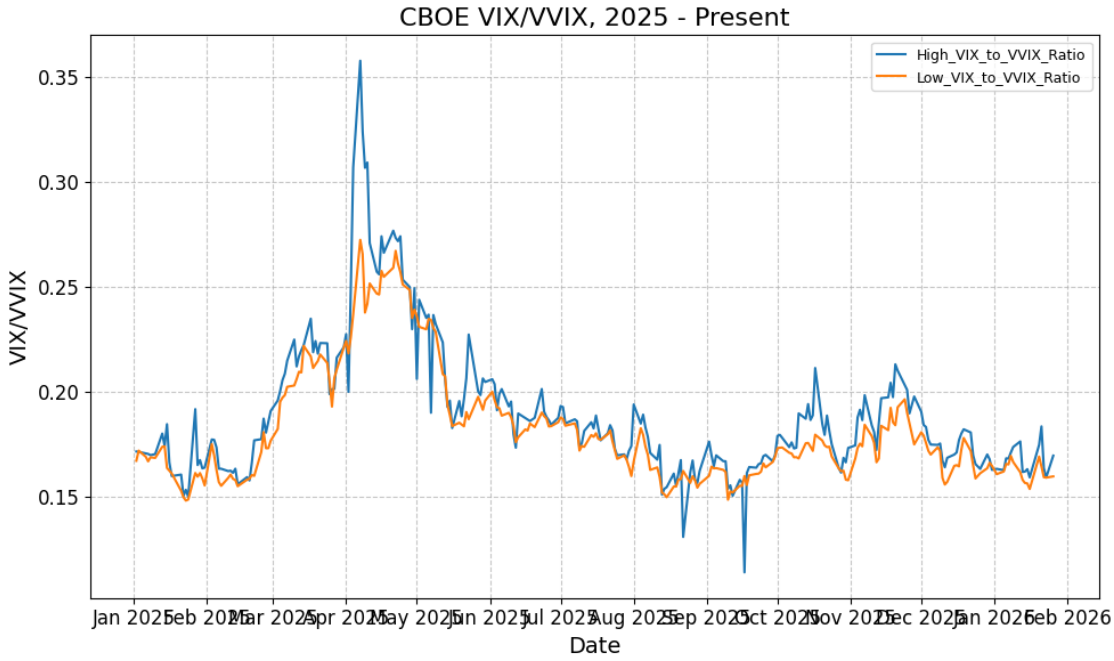


[72]:
```
plot_timeseries(
    price_df=vix_over_vvix,
    plot_start_date="2024-01-01",
    plot_end_date=None,
    plot_columns=["High_VIX_to_VVIX_Ratio", "Low_VIX_to_VVIX_Ratio"],
    title="CBOE VIX/VVIX, 2024 - Present",
    x_label="Date",
    x_format="Month",
    y_label="VIX/VVIX",
    y_format="Decimal",
    y_format_decimal_places=2,
    y_tick_spacing=0.05,
```

```
    grid=True,
    legend=True,
    export_plot=True,
    plot_file_name="03_VIX_Over_VVIX_Plot_2024-Present",
)
```



[73]:
```
plot_timeseries(
    price_df=vix_over_vvix,
    plot_start_date="2025-01-01",
    plot_end_date=None,
    plot_columns=["High_VIX_to_VVIX_Ratio", "Low_VIX_to_VVIX_Ratio"],
    title="CBOE VIX/VVIX, 2025 - Present",
    x_label="Date",
    x_format="Month",
    y_label="VIX/VVIX",
    y_format="Decimal",
    y_format_decimal_places=2,
    y_tick_spacing=0.05,
    grid=True,
    legend=True,
    export_plot=True,
    plot_file_name="03_VIX_Over_VVIX_Plot_2025-Present",
)
```



1.11.3 Stats By Year - VIX/VVIX

[74]:
```
# plot_stats(
#     stats_df=vvix_stats_by_year,
#     plot_columns=["Open_mean", "High_mean", "Low_mean", "Close_mean"],
#     title="VVIX Mean OHLC By Year",
#     x_label="Year",
#     x_rotation=45,
#     x_tick_spacing=1,
#     y_label="Price",
#     y_tick_spacing=5,
#     grid=True,
#     legend=True,
#     export_plot=True,
#     plot_file_name="02_VVIX_Stats_By_Year"
# )
```

1.11.4 Stats By Month - VIX/VVIX

[75]:
```
# plot_stats(
#     stats_df=vvix_stats_by_month,
#     plot_columns=["Open_mean", "High_mean", "Low_mean", "Close_mean"],
#     title="VVIX Mean OHLC By Month",
#     x_label="Month",
#     x_rotation=0,
```

```
#     x_tick_spacing=1,
#     y_label="Price",
#     y_tick_spacing=1,
#     grid=True,
#     legend=True,
#     export_plot=True,
#     plot_file_name="02_VVIX_Stats_By_Month"
# )
```

1.12 Investigating A Signal

1.12.1 Determining A Spike Level

[76]:
```
# 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()
```

[77]:
```
display(vix)
```

```
            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
…           …    …    …    …           …                  …
2026-01-20  20.09 20.99 18.64 19.94        16.74              16.17
2026-01-21  16.90 20.81 16.67 19.31        17.30              16.74
2026-01-22  15.64 16.67 15.27 16.65        17.42              17.30
2026-01-23  16.09 16.21 15.30 15.68        17.46              17.42
2026-01-26  16.15 17.39 15.80 16.90        17.62              17.46

            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
…                       …            …        …              …          …
2026-01-20            20.21        15.88       True        18.32        17.17
2026-01-21            20.93        16.10      False        18.33        17.83
2026-01-22            21.63        16.17      False        18.21        17.62
2026-01-23            21.78        16.26      False        18.15        17.36
2026-01-26            21.82        16.42      False        18.14        17.37

            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
…                       …                …            …          …
2026-01-20              16.32            20.40        16.80       True
2026-01-21              17.17            21.46        17.18      False
2026-01-22              17.83            22.29        17.13      False
2026-01-23              17.62            22.03        17.04      False
2026-01-26              17.36            21.71        17.08      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
…                 …
2026-01-20        17.45
2026-01-21        17.59
2026-01-22        17.55
2026-01-23        17.50
2026-01-26        17.49

[9083 rows x 16 columns]
```

[78]:
```
vix[vix['High'] >= 50]
```

[78]:
```
            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
…           …    …    …    …            …                  …
2024-08-05  38.57 65.73 23.39 23.39        23.84              18.95
2025-04-07  46.98 60.13 38.58 60.13        28.60              24.51
2025-04-08  52.33 57.52 36.48 44.04        32.58              28.60
2025-04-09  33.62 57.96 31.90 50.98        36.47              32.58
2025-04-10  40.72 54.87 34.44 34.44        40.03              36.47

            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
…                     …          …         …         …          …
2024-08-05            23.69        19.11       True        15.66        28.04
2025-04-07            30.63        26.10       True        22.35        33.61
2025-04-08            35.76        27.50       True        23.05        37.96
2025-04-09            40.72        29.05       True        23.84        41.60
2025-04-10            45.59        30.49       True        24.58        44.01

            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
…                       …              …          …         …
2024-08-05              19.66            24.58        22.15       True
2025-04-07              27.72            34.65        28.48       True
2025-04-08              33.61            42.01        31.25       True
2025-04-09              37.96            47.45        33.79       True
2025-04-10              41.60            51.99        35.80       True

            High_EMA_50
Date
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
…                 …
2024-08-05        17.62
2025-04-07        23.95
2025-04-08        25.27
2025-04-09        26.55
2025-04-10        27.66

[97 rows x 16 columns]
```

1.12.2 Spike Counts (Signals) By Year

[79]:
```python
# 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)

display(spike_count_SMA)
```

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	231	19
2026	15	1

[80]:
```
# Copy this <!-- INSERT_08_Spike_Counts_HERE --> to index_temp.md
export_track_md_deps(dep_file=dep_file, md_filename="08_Spike_Counts.md",␣
 ↪content=spike_count_SMA.to_markdown())
```

```
Exported and tracked: 08_Spike_Counts.md
```

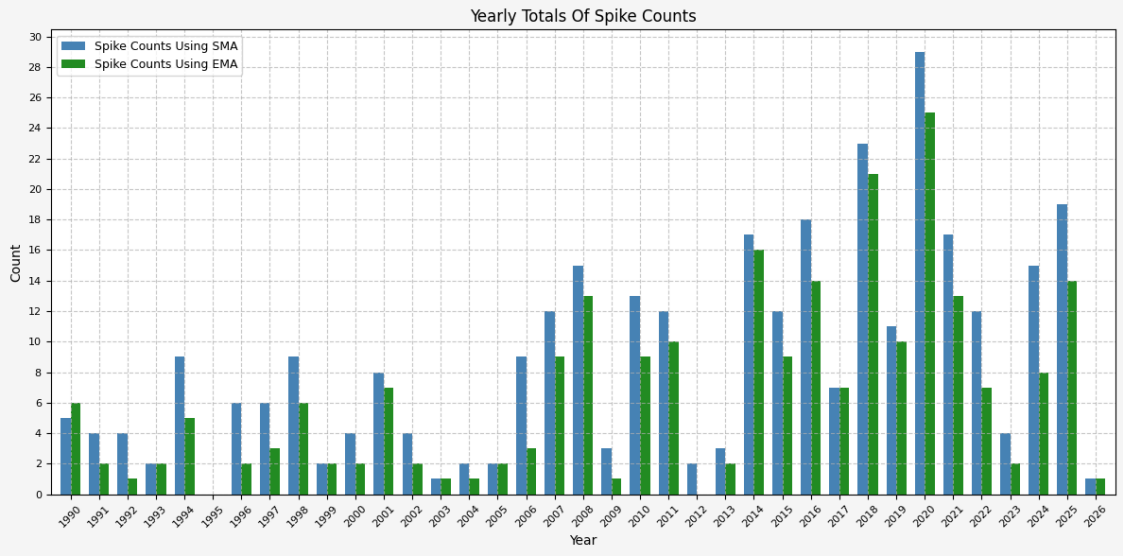
[81]:
```
# Ensure the index is a DatetimeIndex
vix.index = pd.to_datetime(vix.index)

# 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)

display(spike_count_EMA)
```

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          236      14
2026           15       1
```

[82]:
```python
# 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()
```



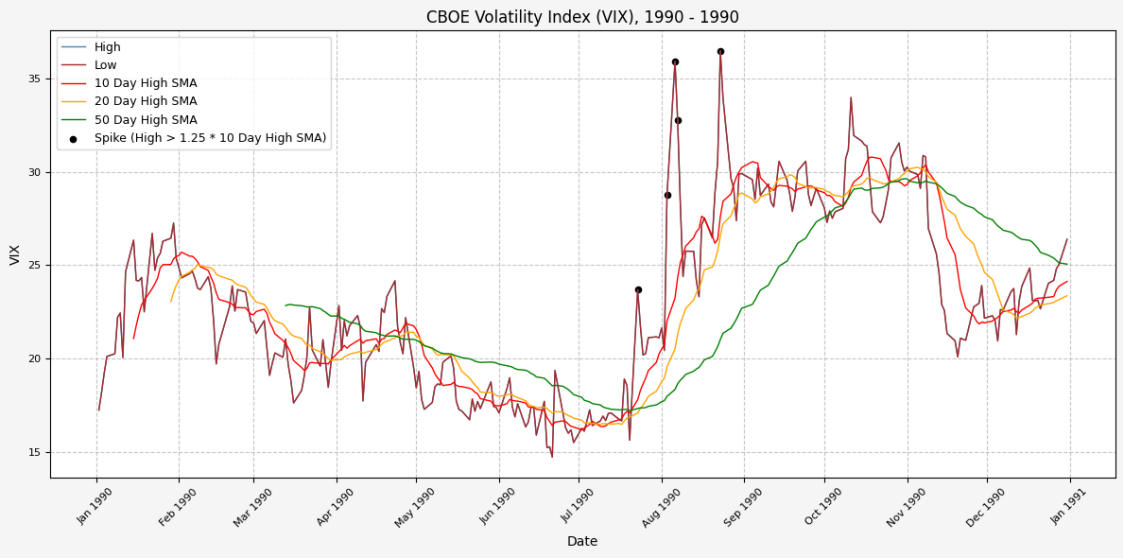
1.12.3 Spike Counts (Signals) Plots By Year

[83]:
```
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()
```

Yearly Plots

[84]:
```
for year in range(1990, 2026):
    vix_plot(str(year), str(year))
```


CBOE Volatility Index (VIX), 1990 - 1990
High
Low
10 Day High SMA
20 Day High SMA
50 Day High SMA
Spike (High > 1.25 * 10 Day High SMA)
VIX
Date
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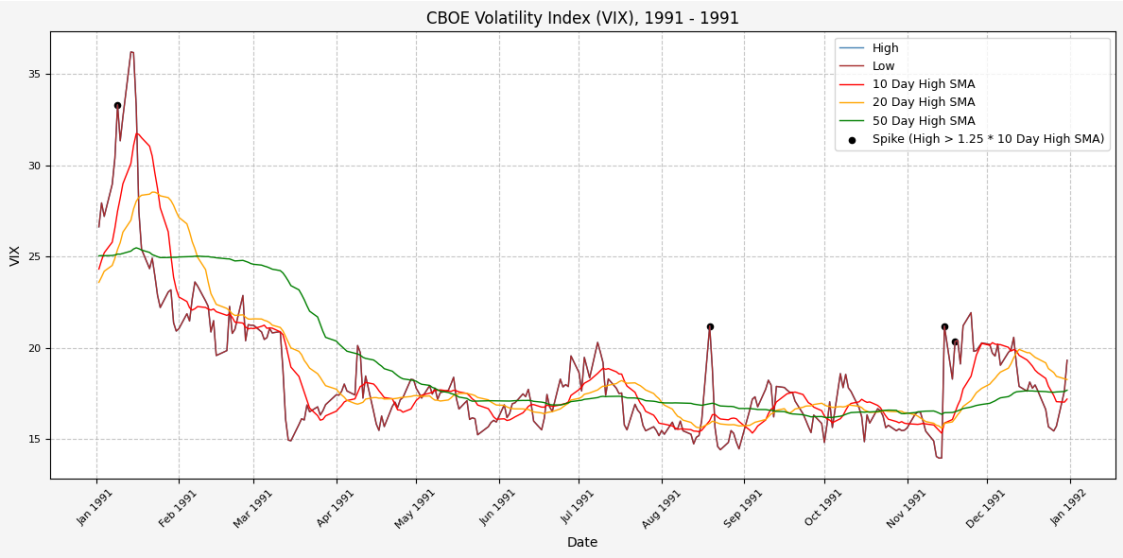
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High
Low
10 Day High SMA
20 Day High SMA
50 Day High SMA
Spike (High > 1.25 * 10 Day High SMA)
VIX
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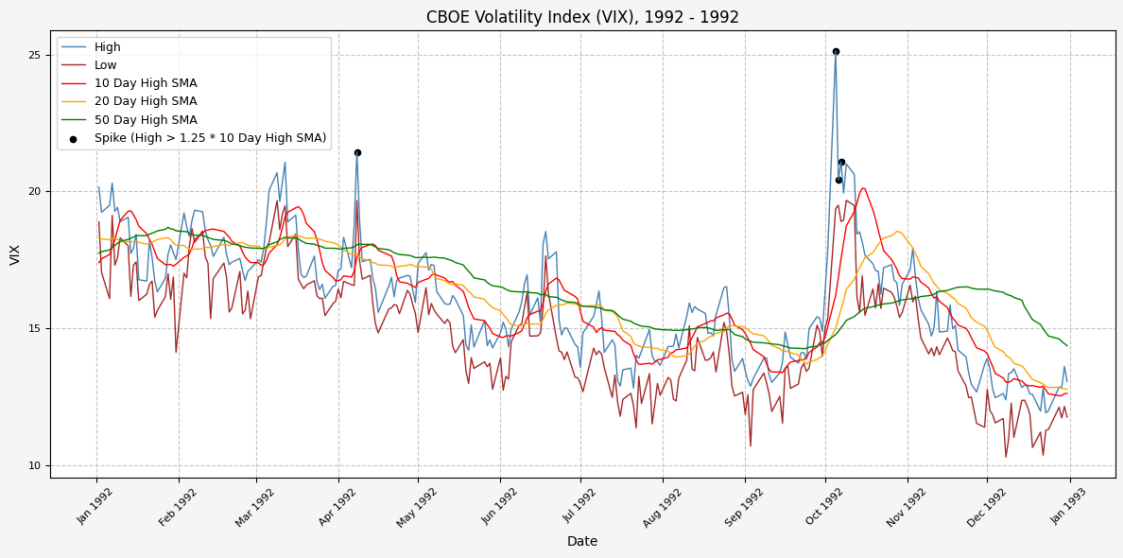
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High
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20 Day High SMA
50 Day High SMA
Spike (High > 1.25 * 10 Day High SMA)
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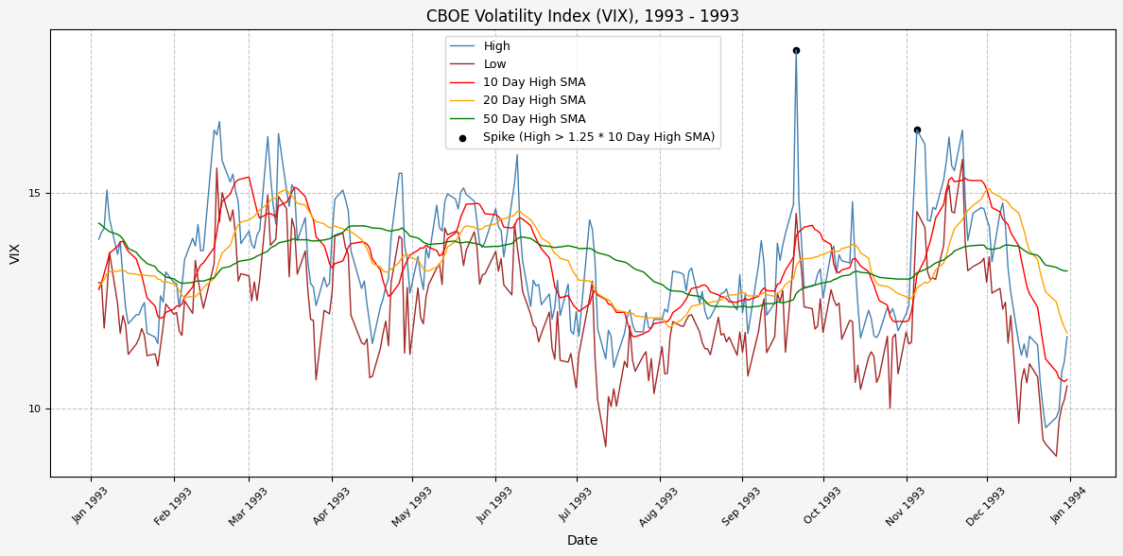
CBOE Volatility Index (VIX), 1993 - 1993
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20 Day High SMA
50 Day High SMA
Spike (High > 1.25 * 10 Day High SMA)
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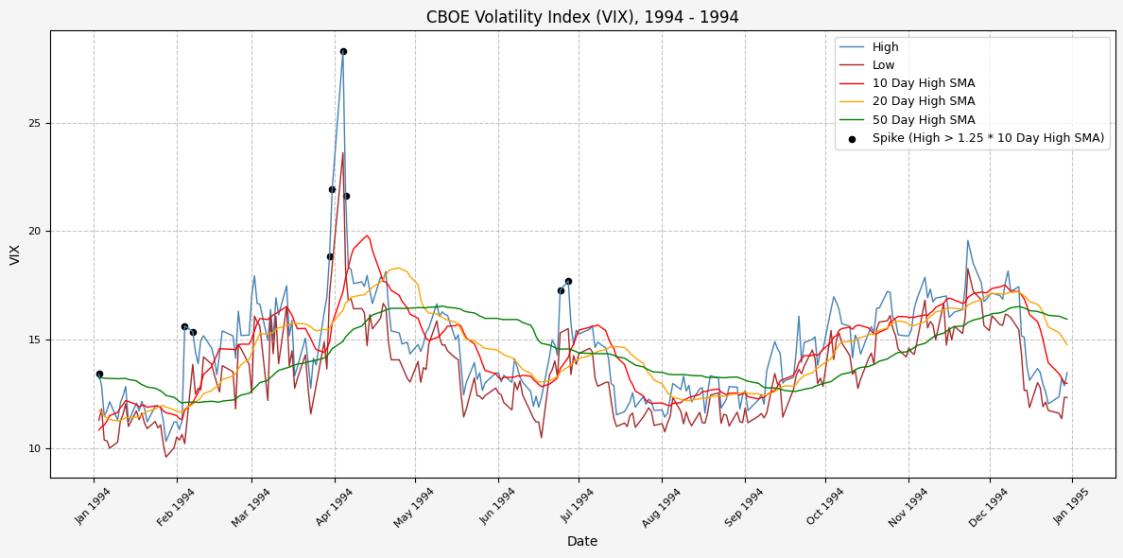
CBOE Volatility Index (VIX), 1994 - 1994
High
Low
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20 Day High SMA
50 Day High SMA
Spike (High > 1.25 * 10 Day High SMA)
VIX
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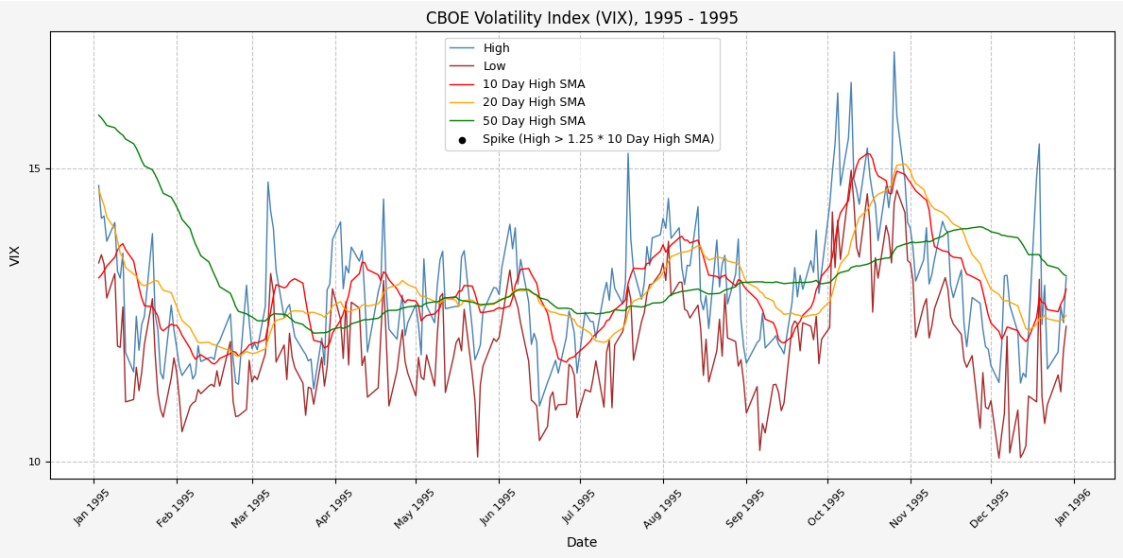
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50 Day High SMA
Spike (High > 1.25 * 10 Day High SMA)
VIX
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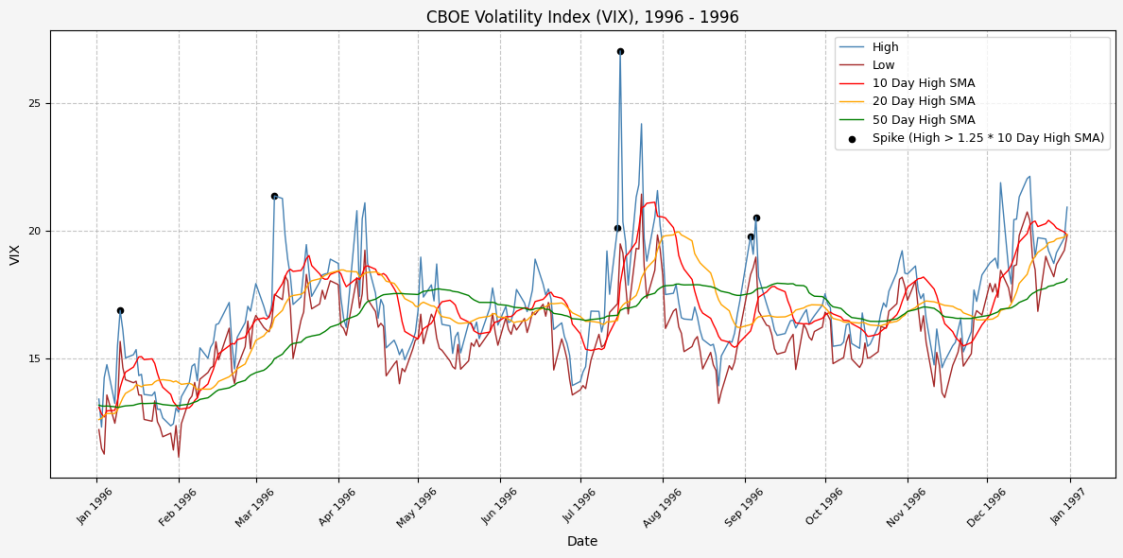
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20 Day High SMA
50 Day High SMA
Spike (High > 1.25 * 10 Day High SMA)
VIX
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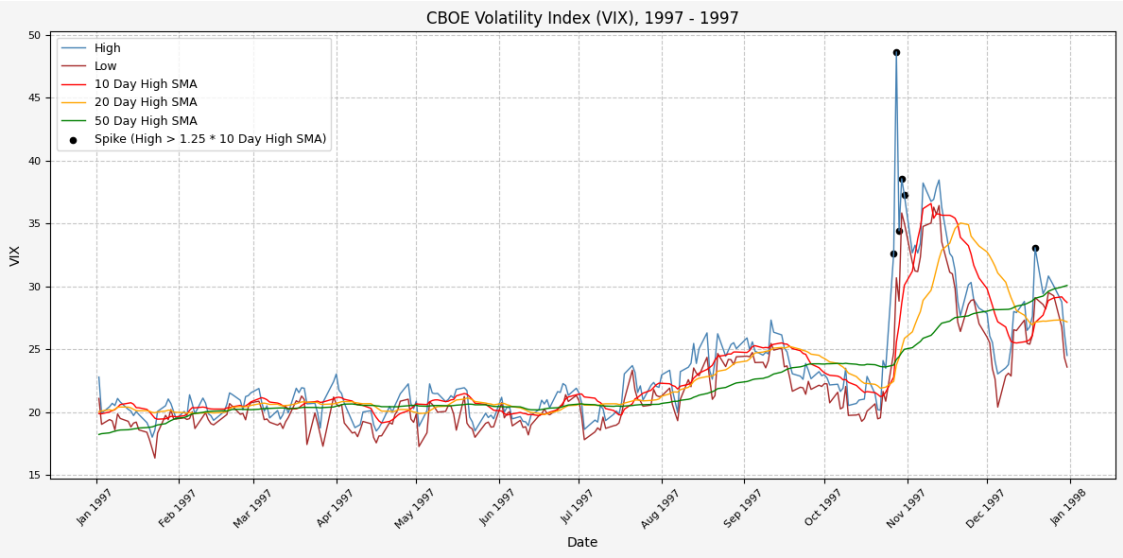
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20 Day High SMA
50 Day High SMA
Spike (High > 1.25 * 10 Day High SMA)
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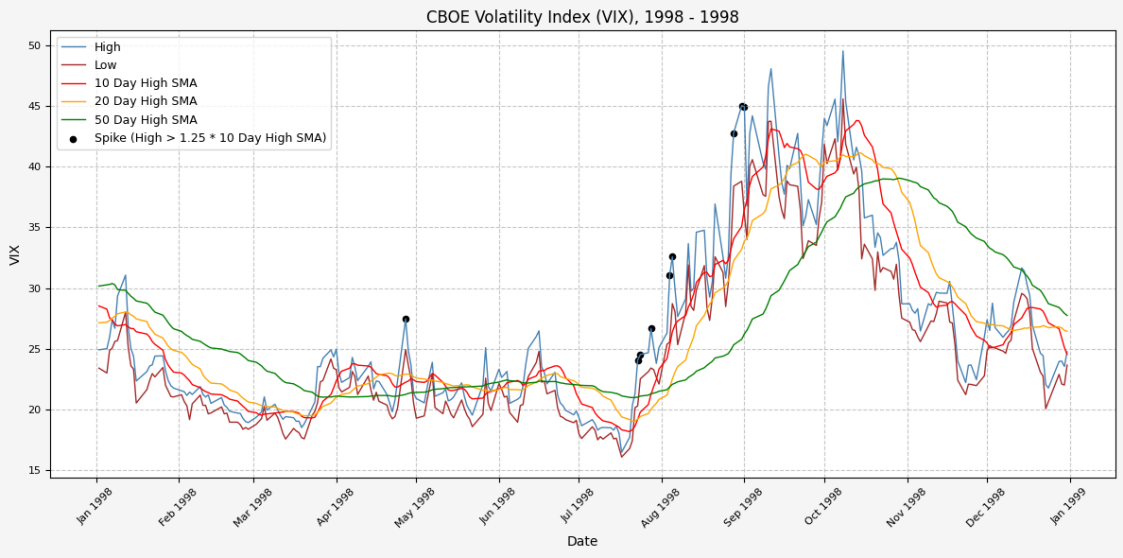
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Low
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50 Day High SMA
Spike (High > 1.25 * 10 Day High SMA)
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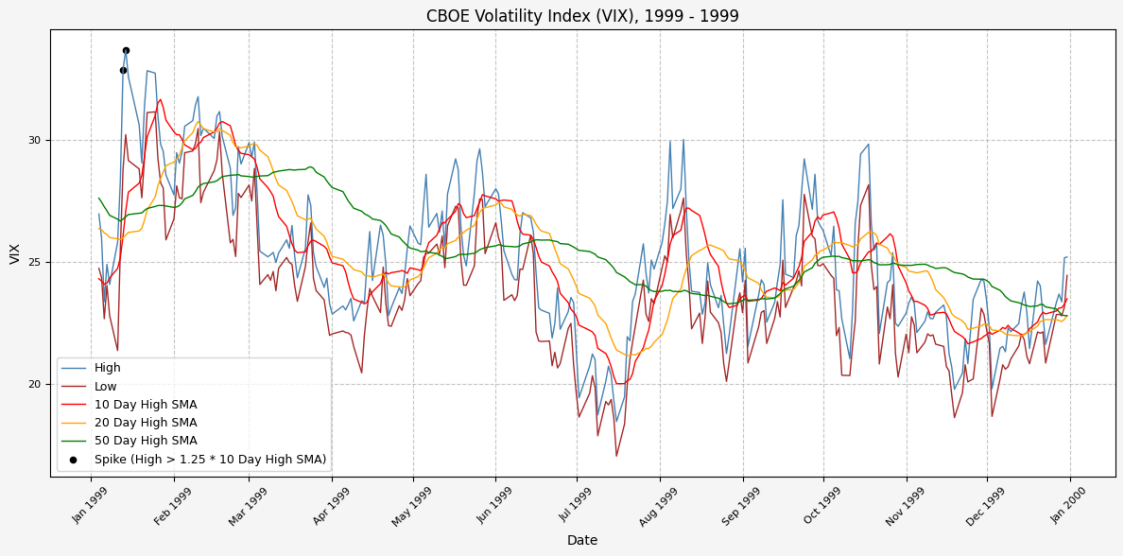
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Spike (High > 1.25 * 10 Day High SMA)
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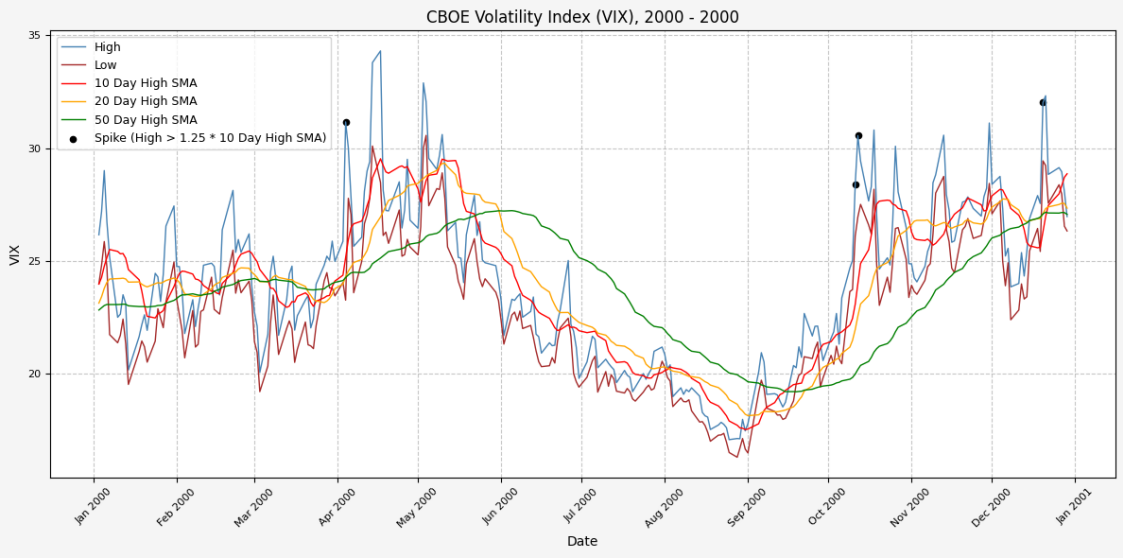
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50 Day High SMA
Spike (High > 1.25 * 10 Day High SMA)
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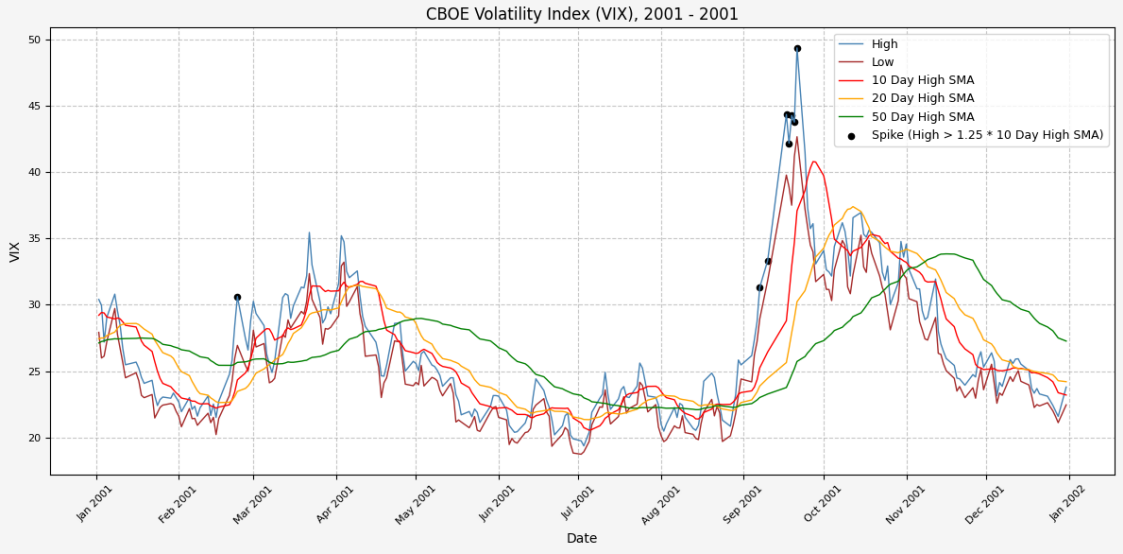
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Spike (High > 1.25 * 10 Day High SMA)
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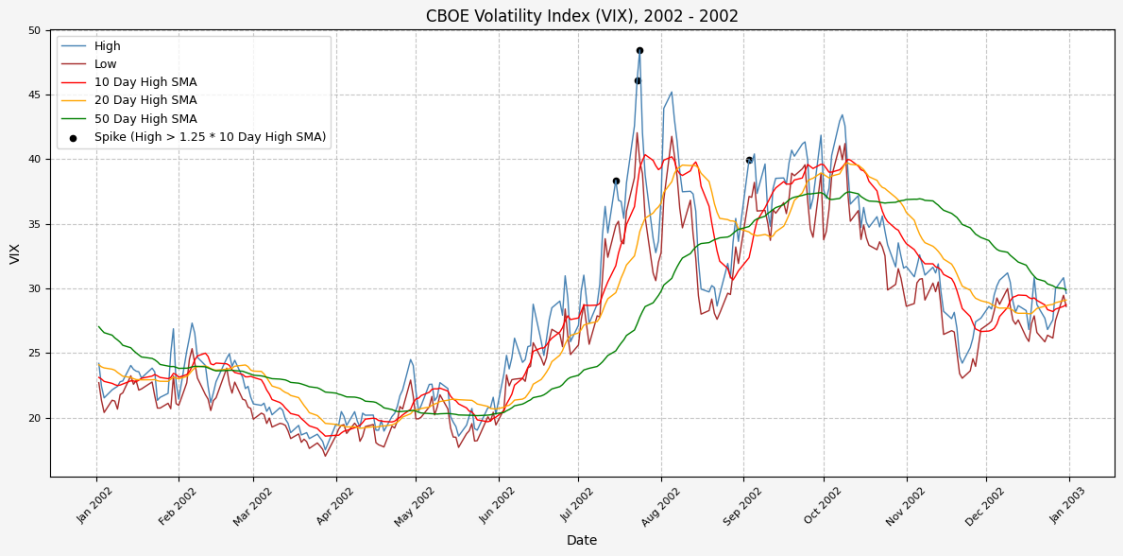
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50 Day High SMA
Spike (High > 1.25 * 10 Day High SMA)
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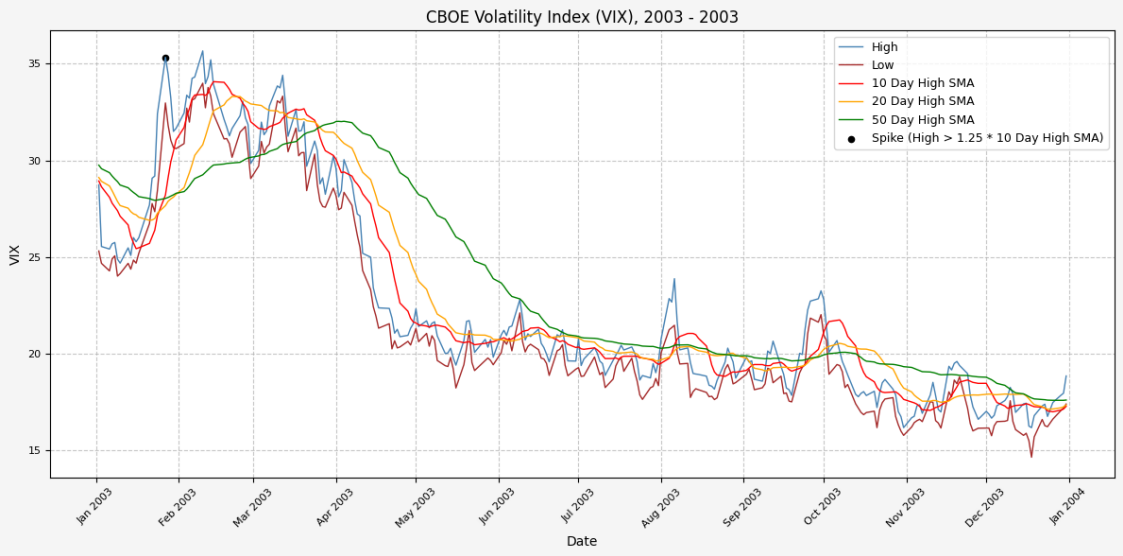
CBOE Volatility Index (VIX), 2003 - 2003
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50 Day High SMA
Spike (High > 1.25 * 10 Day High SMA)
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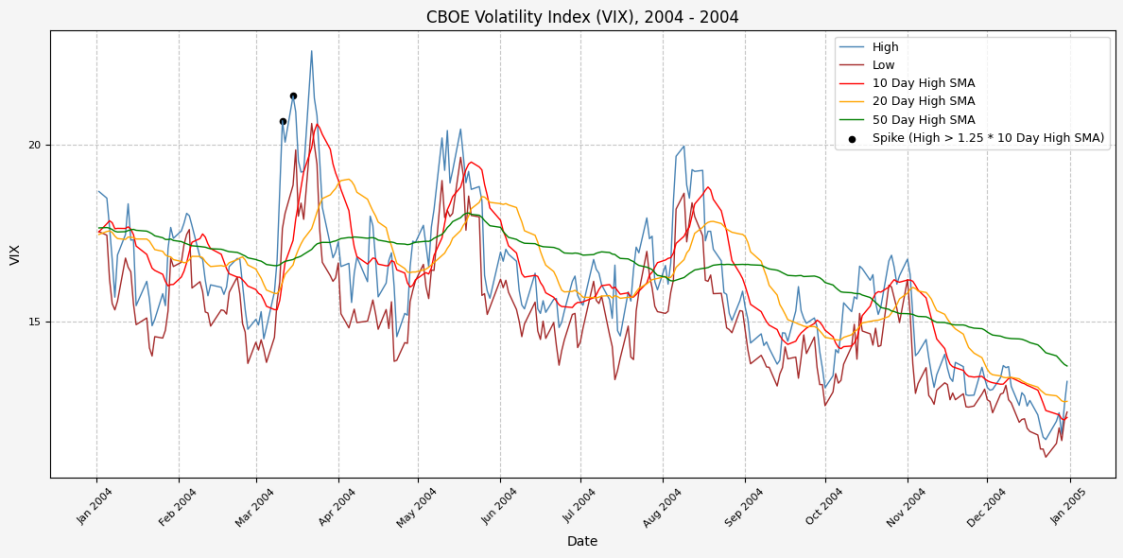
CBOE Volatility Index (VIX), 2004 - 2004
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50 Day High SMA
Spike (High > 1.25 * 10 Day High SMA)
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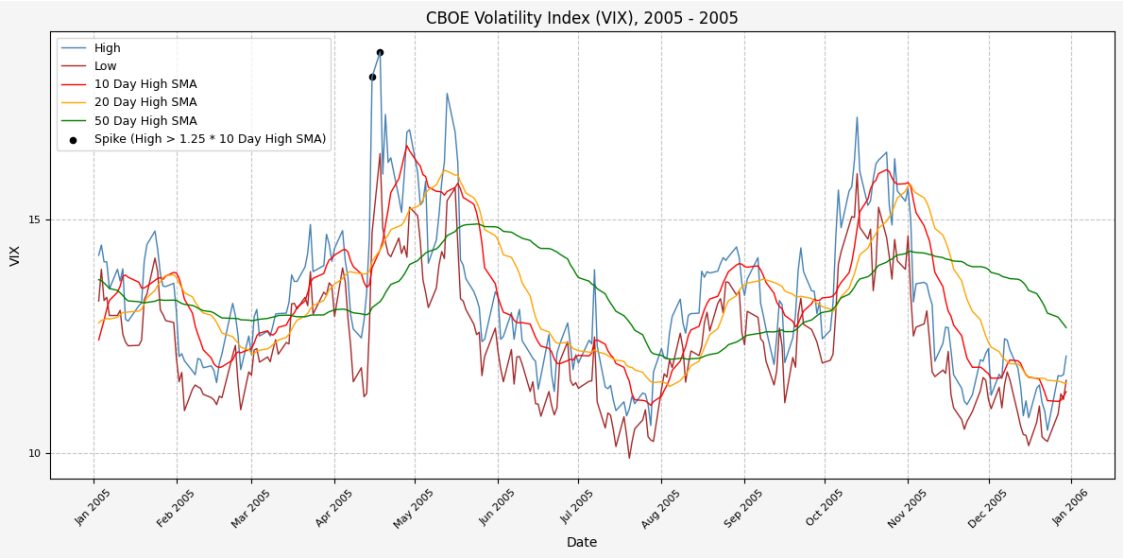
CBOE Volatility Index (VIX), 2005 - 2005
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Spike (High > 1.25 * 10 Day High SMA)
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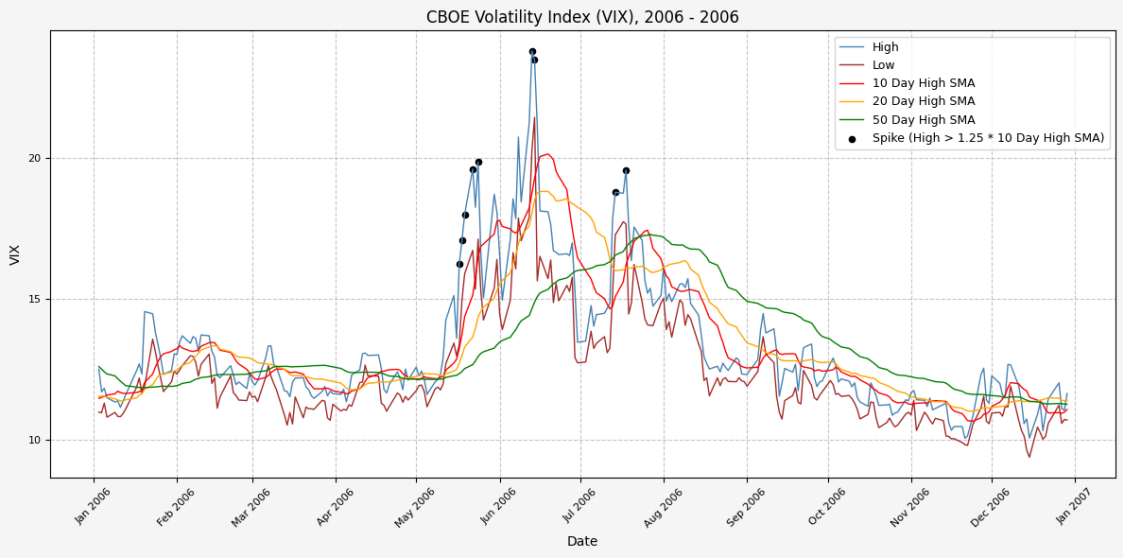
CBOE Volatility Index (VIX), 2006 - 2006
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Spike (High > 1.25 * 10 Day High SMA)
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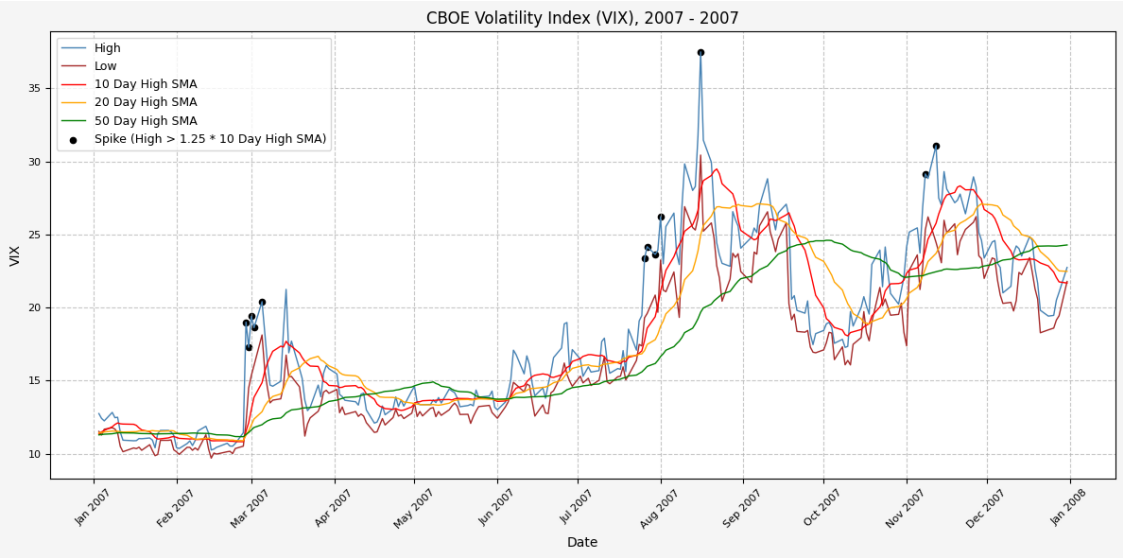
CBOE Volatility Index (VIX), 2007 - 2007
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50 Day High SMA
Spike (High > 1.25 * 10 Day High SMA)
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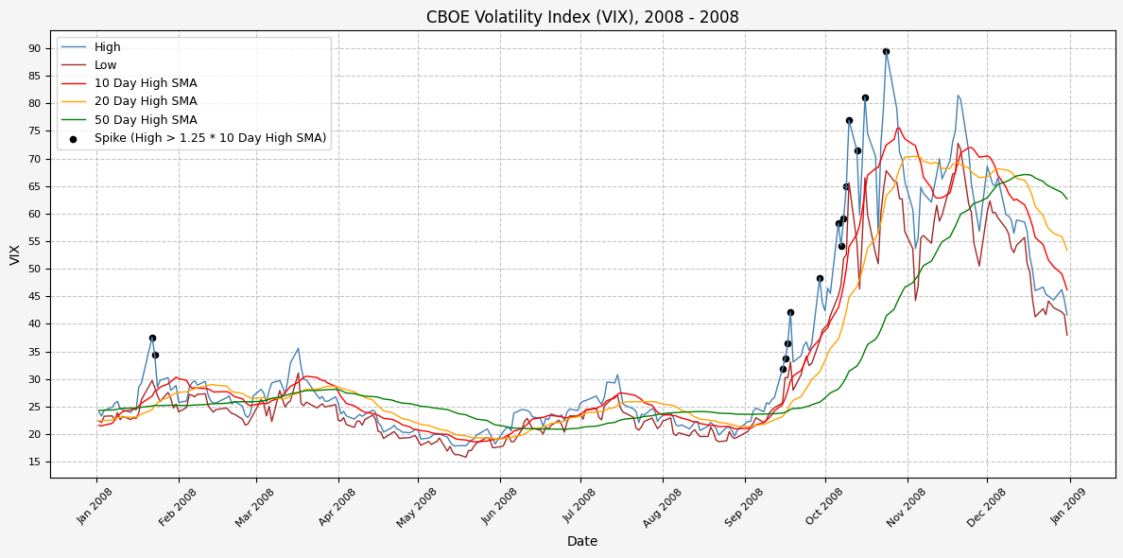
CBOE Volatility Index (VIX), 2008 - 2008
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Spike (High > 1.25 * 10 Day High SMA)
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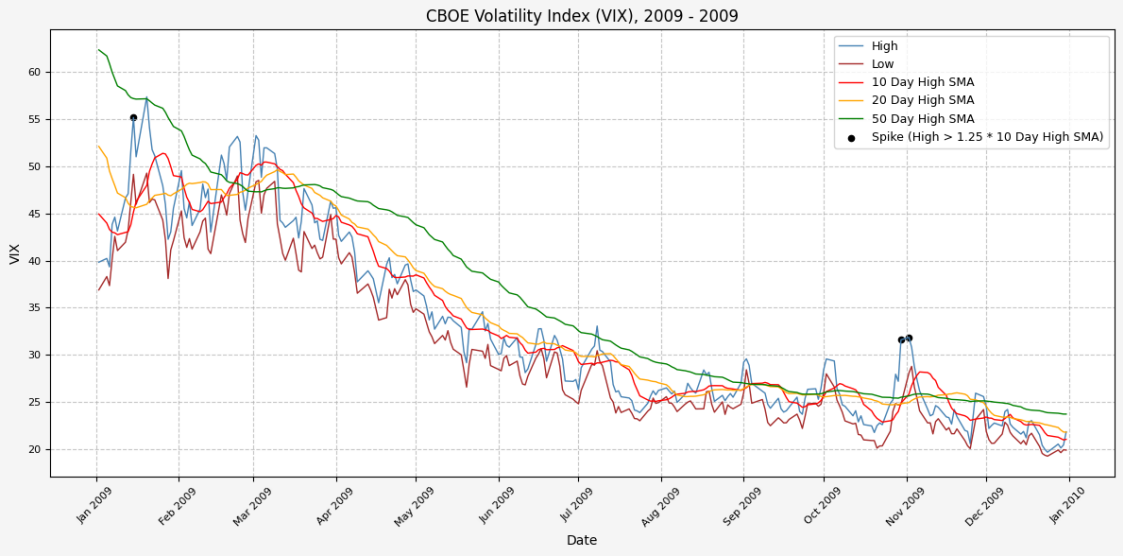
CBOE Volatility Index (VIX), 2009 - 2009
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Spike (High > 1.25 * 10 Day High SMA)
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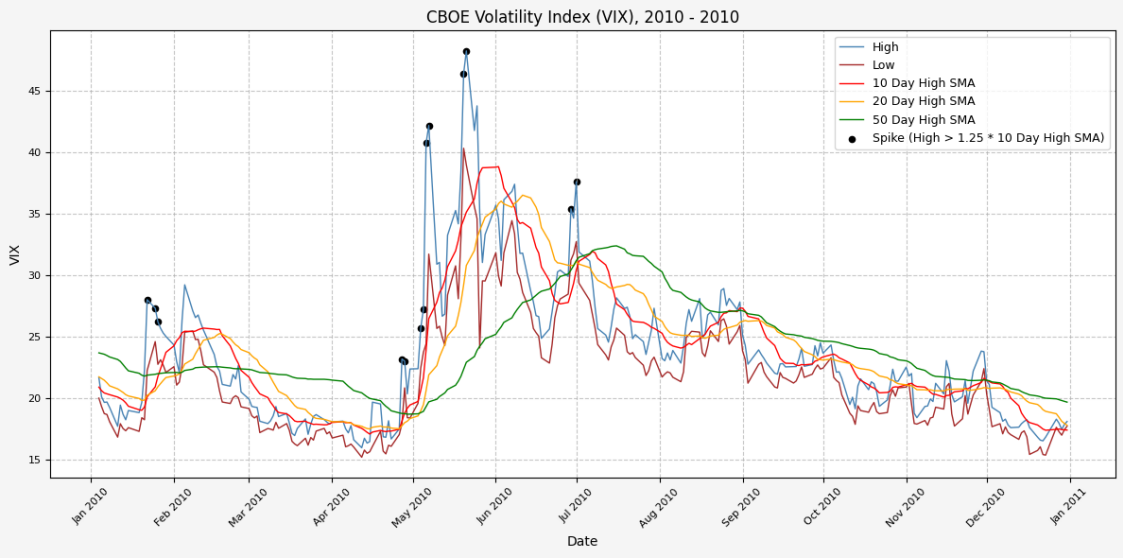
CBOE Volatility Index (VIX), 2010 - 2010
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20 Day High SMA
50 Day High SMA
Spike (High > 1.25 * 10 Day High SMA)
VIX
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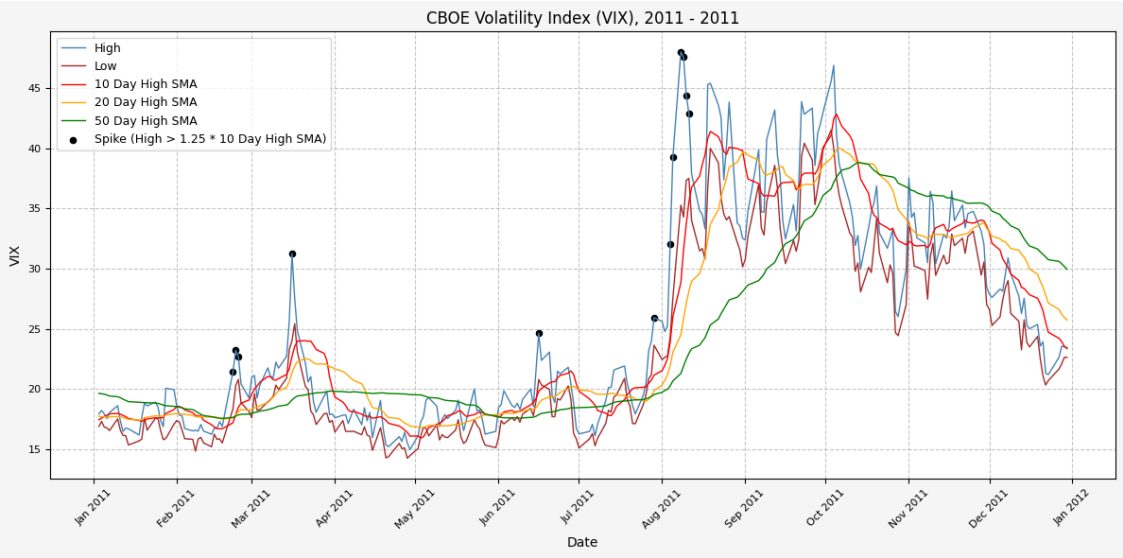
CBOE Volatility Index (VIX), 2011 - 2011
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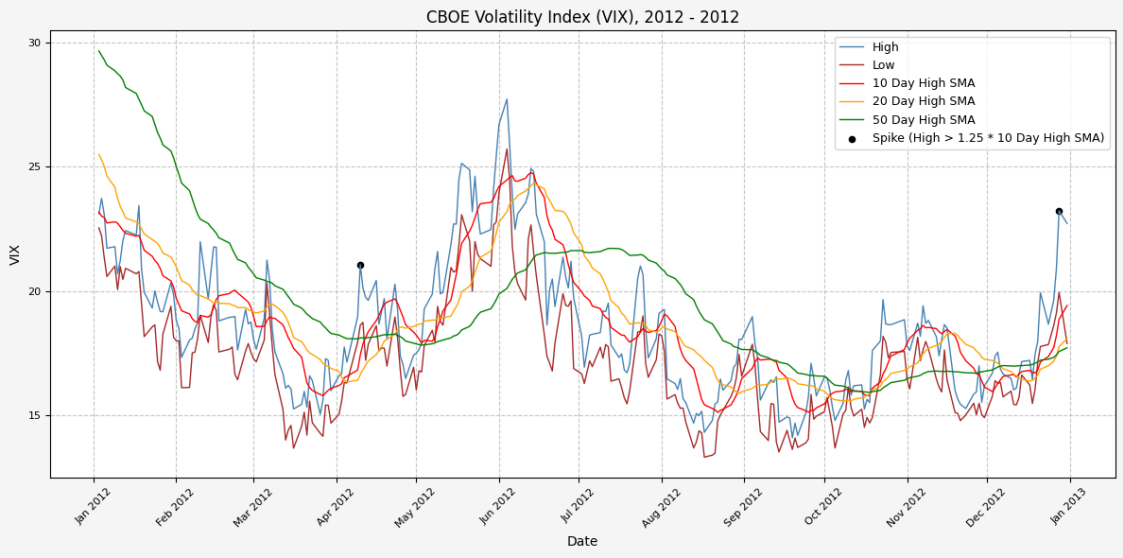
CBOE Volatility Index (VIX), 2012 - 2012
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Low
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50 Day High SMA
Spike (High > 1.25 * 10 Day High SMA)
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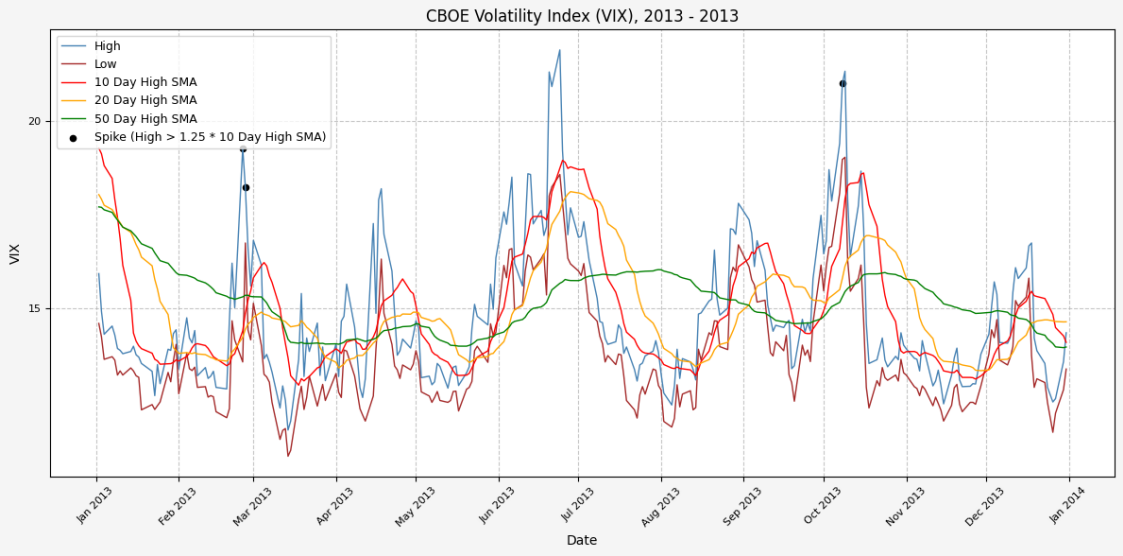
CBOE Volatility Index (VIX), 2013 - 2013
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50 Day High SMA
Spike (High > 1.25 * 10 Day High SMA)
VIX
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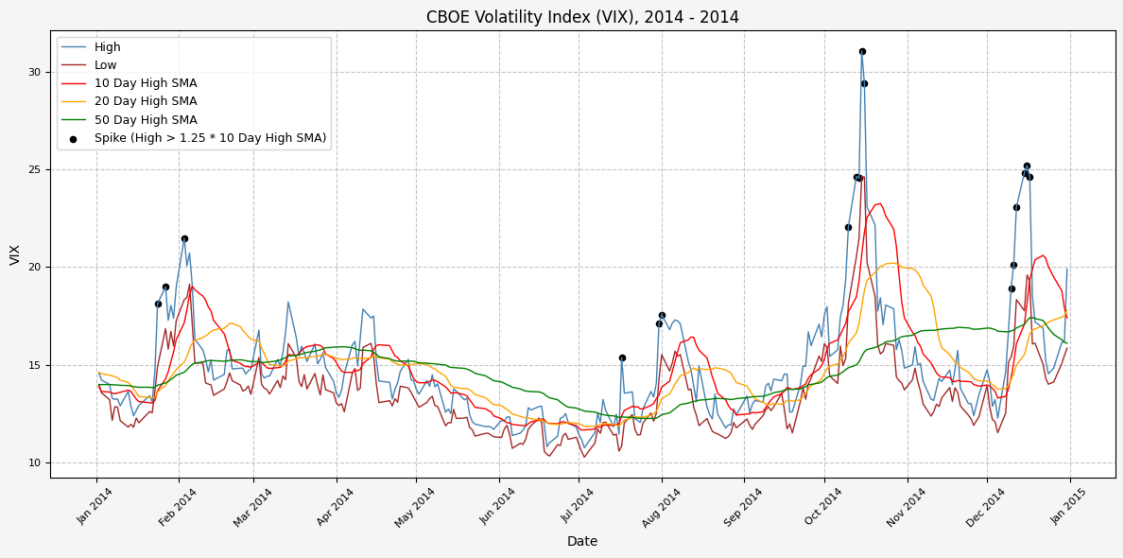
CBOE Volatility Index (VIX), 2014 - 2014
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Spike (High > 1.25 * 10 Day High SMA)
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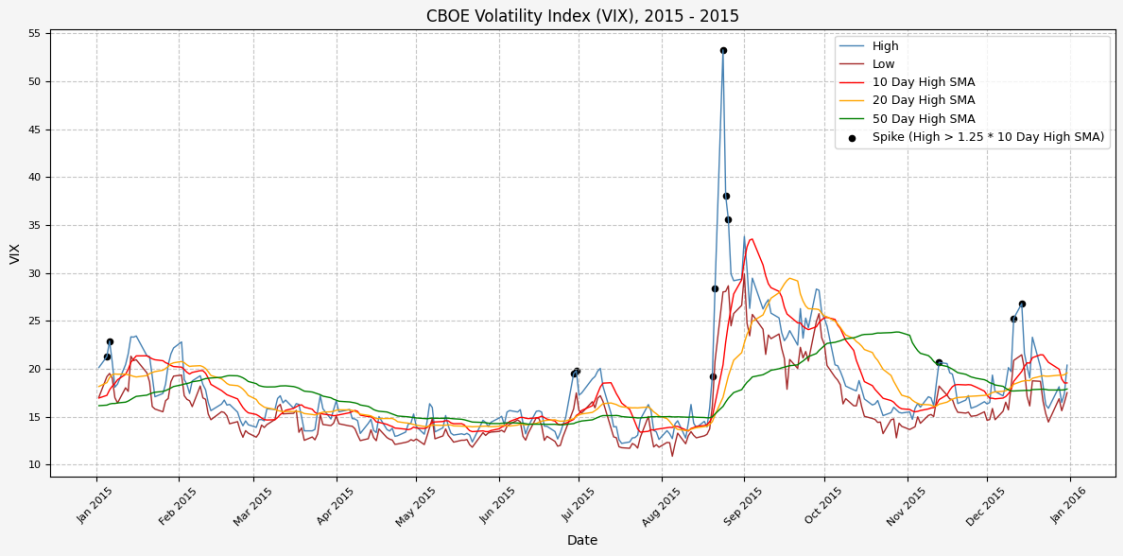
CBOE Volatility Index (VIX), 2015 - 2015
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Spike (High > 1.25 * 10 Day High SMA)
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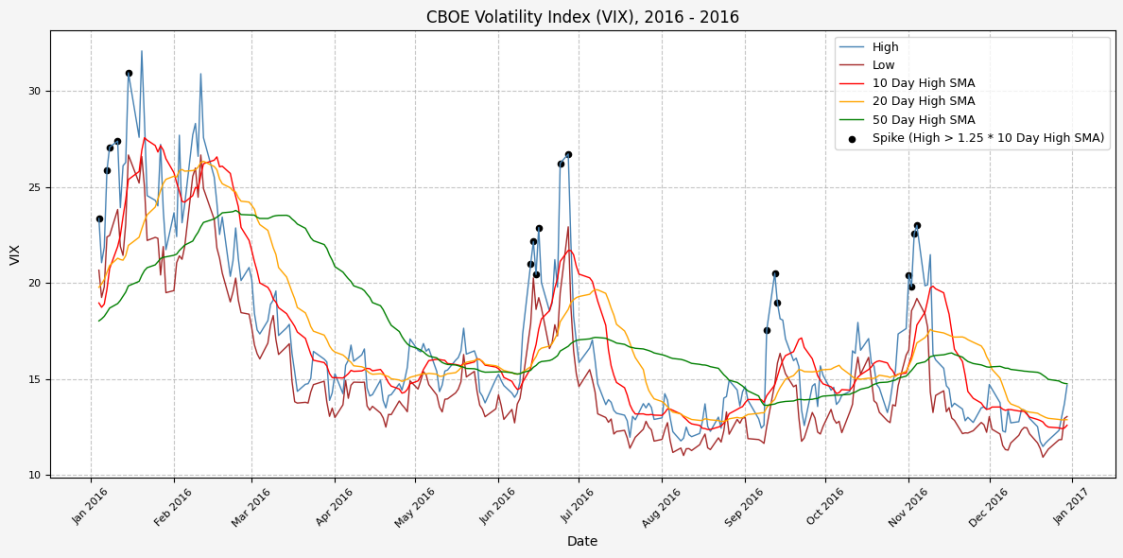
CBOE Volatility Index (VIX), 2016 - 2016
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50 Day High SMA
Spike (High > 1.25 * 10 Day High SMA)
VIX
Date
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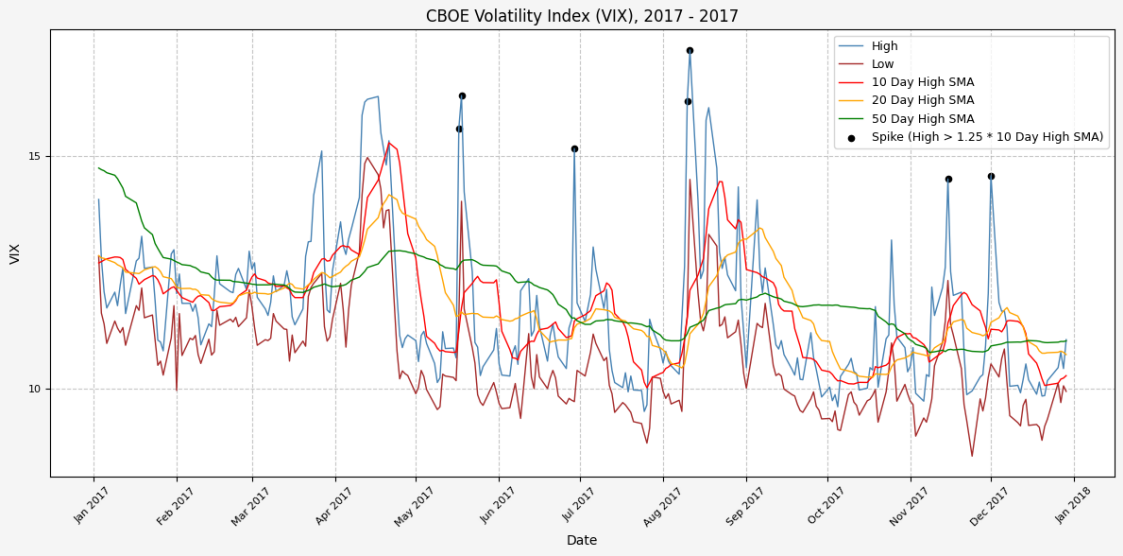
CBOE Volatility Index (VIX), 2017 - 2017
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Spike (High > 1.25 * 10 Day High SMA)
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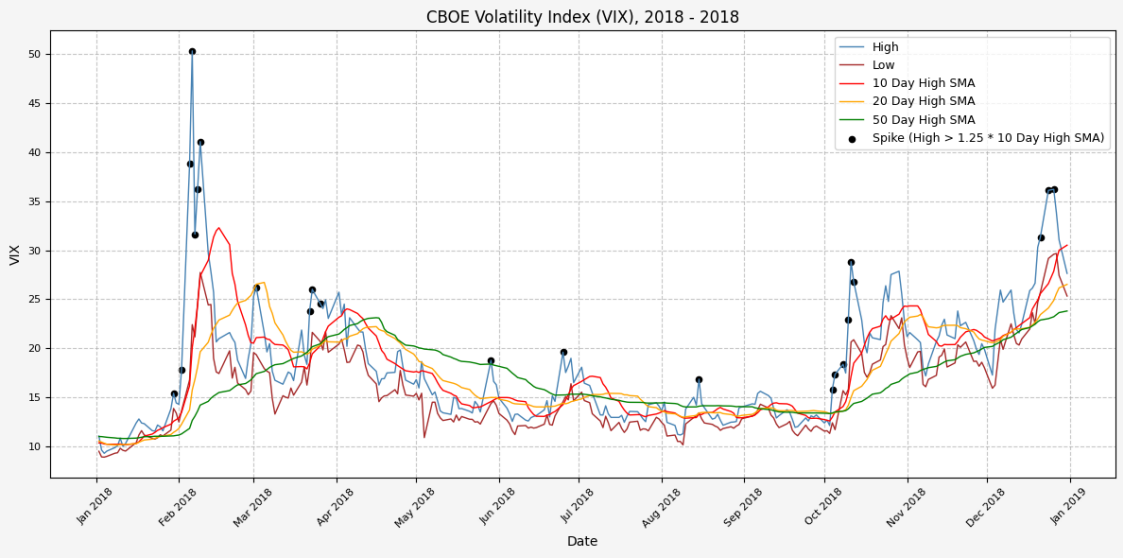
CBOE Volatility Index (VIX), 2018 - 2018
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20 Day High SMA
50 Day High SMA
Spike (High > 1.25 * 10 Day High SMA)
VIX
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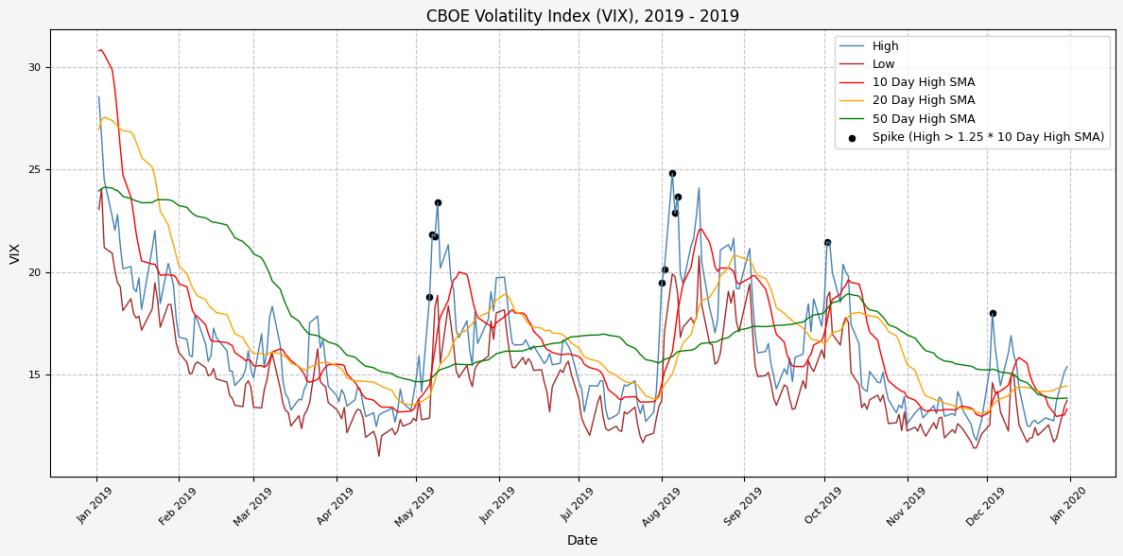
CBOE Volatility Index (VIX), 2019 - 2019
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Low
10 Day High SMA
20 Day High SMA
50 Day High SMA
Spike (High > 1.25 * 10 Day High SMA)
VIX
Date
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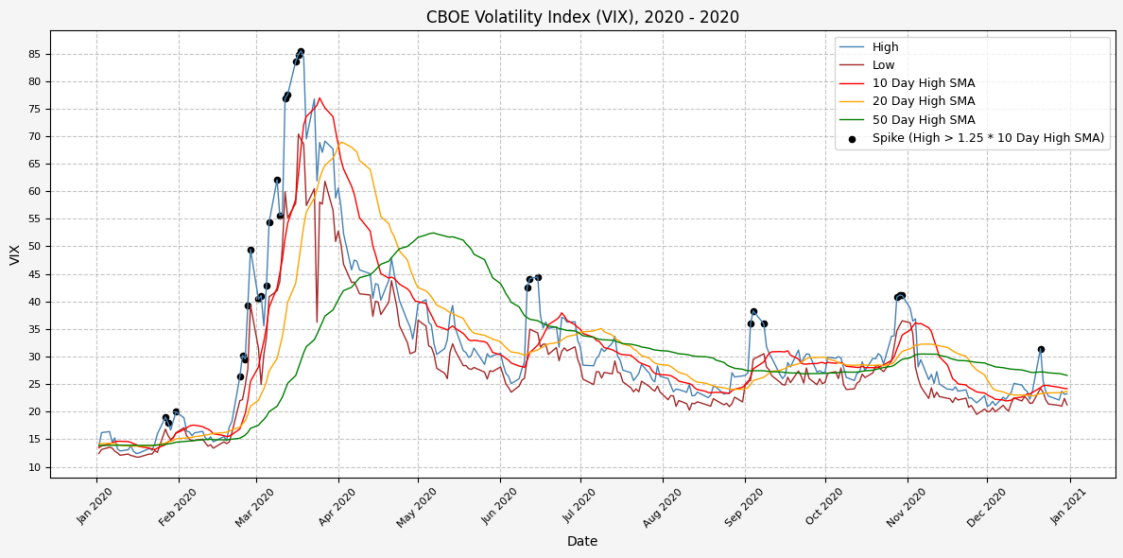
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50 Day High SMA
Spike (High > 1.25 * 10 Day High SMA)
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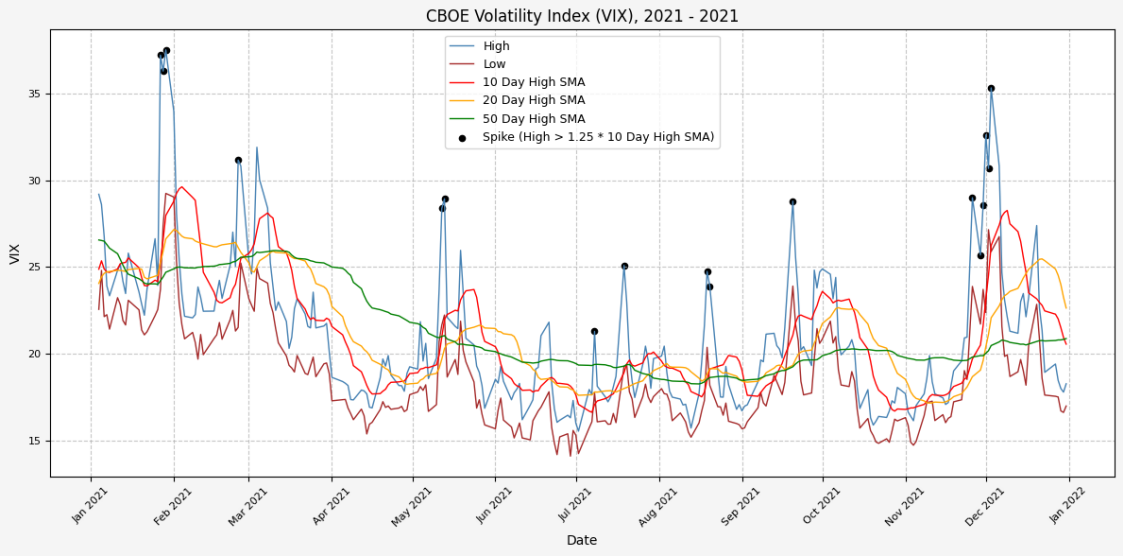
CBOE Volatility Index (VIX), 2021 - 2021
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20 Day High SMA
50 Day High SMA
Spike (High > 1.25 * 10 Day High SMA)
VIX
Date
Jan 2021
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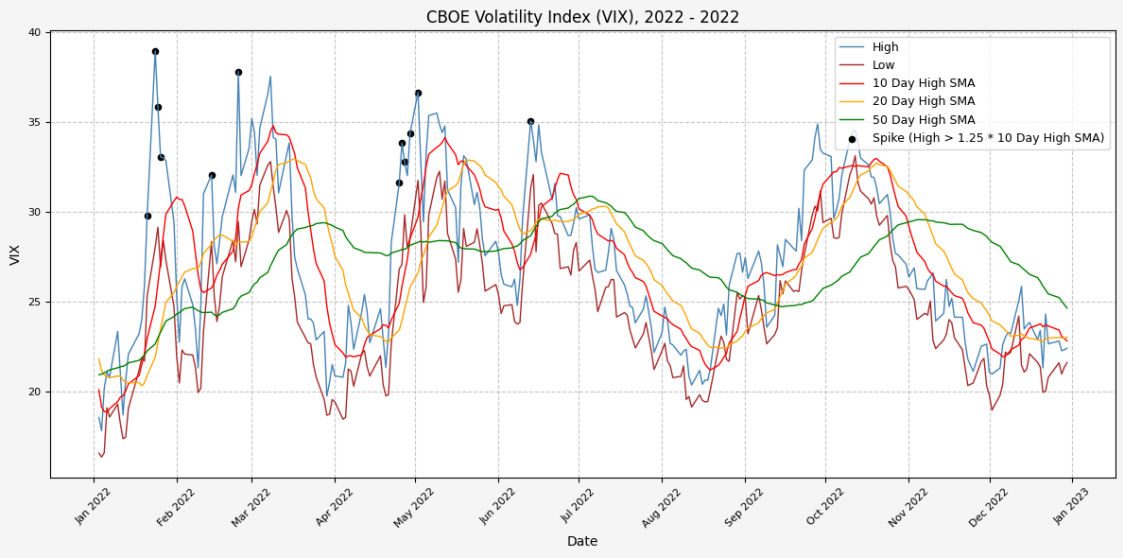
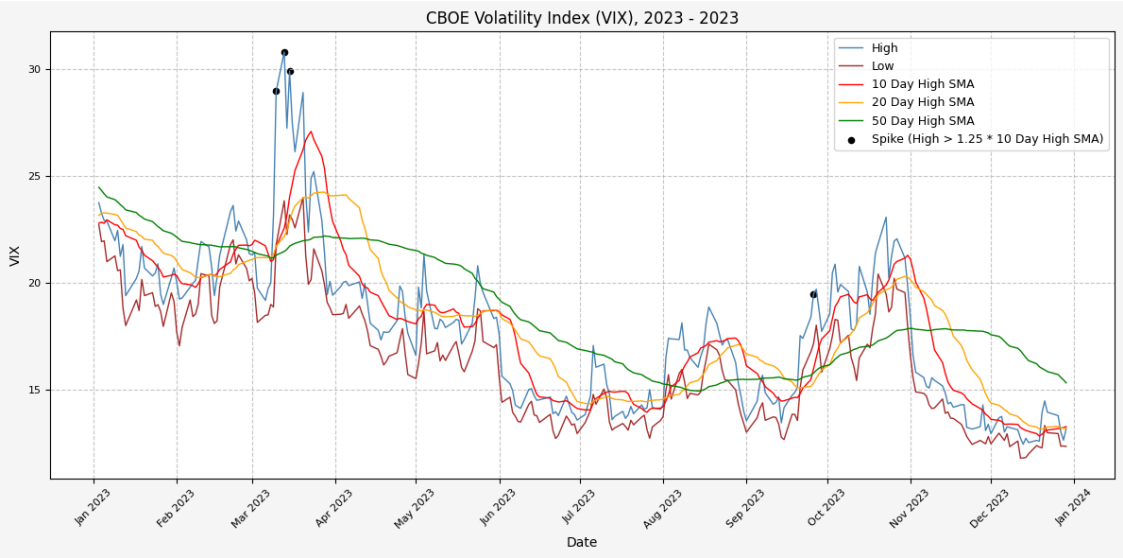
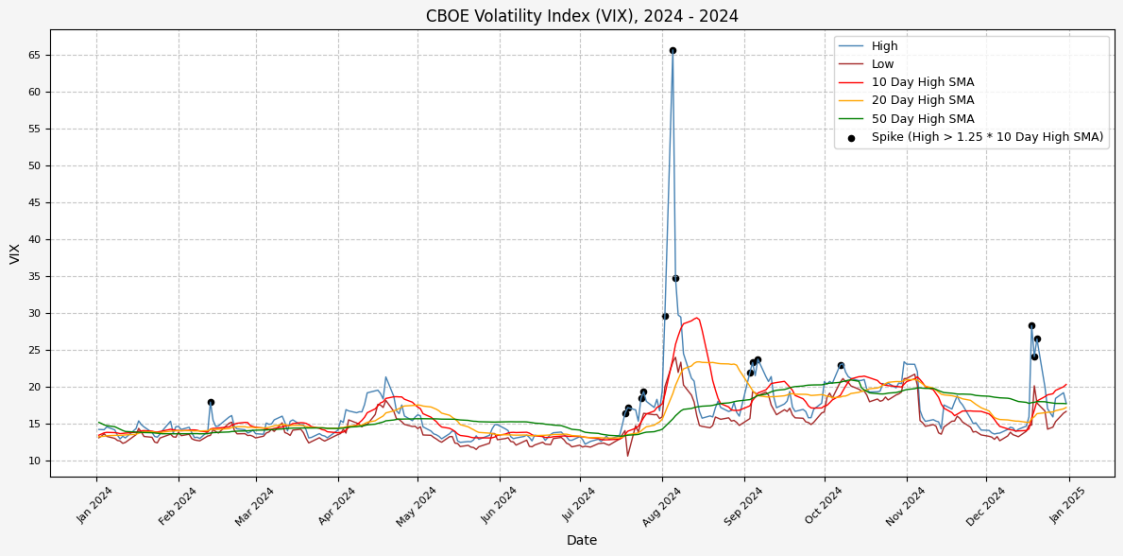
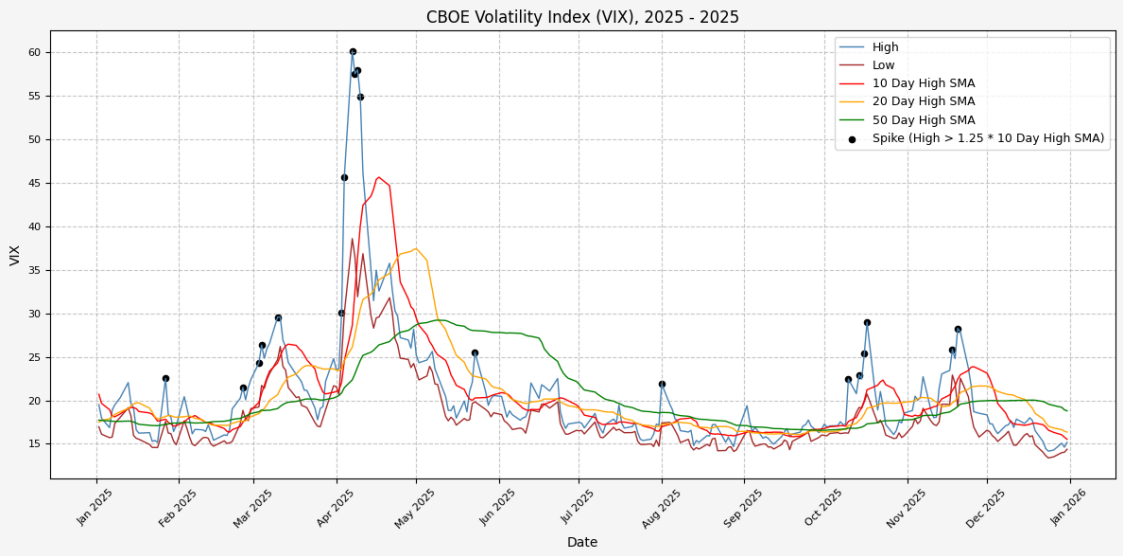
Nov 2021
Dec 2021
Jan 2022


CBOE Volatility Index (VIX), 2022 - 2022
High
Low
10 Day High SMA
20 Day High SMA
50 Day High SMA
Spike (High > 1.25 * 10 Day High SMA)
VIX
Date
Jan 2022
Feb 2022
Mar 2022
Apr 2022
May 2022
Jun 2022
Jul 2022
Aug 2022
Sep 2022
Oct 2022
Nov 2022
Dec 2022
Jan 2023


CBOE Volatility Index (VIX), 2023 - 2023
High
Low
10 Day High SMA
20 Day High SMA
50 Day High SMA
Spike (High > 1.25 * 10 Day High SMA)
VIX
Date
Jan 2023
Feb 2023
Mar 2023
Apr 2023
May 2023
Jun 2023
Jul 2023
Aug 2023
Sep 2023
Oct 2023
Nov 2023
Dec 2023
Jan 2024

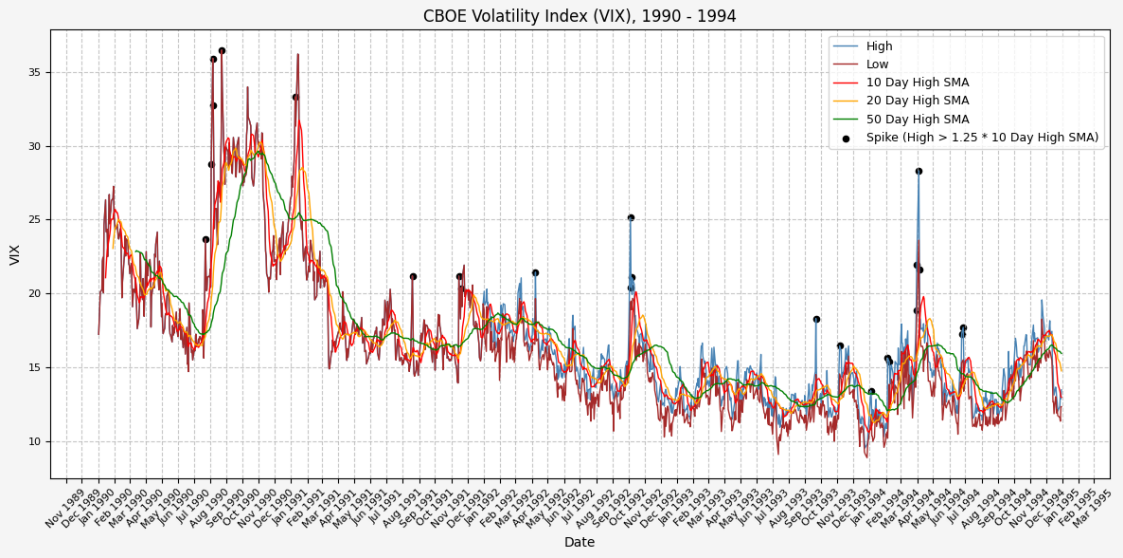




1.12.4 Spike Counts (Signals) Plots By Decade

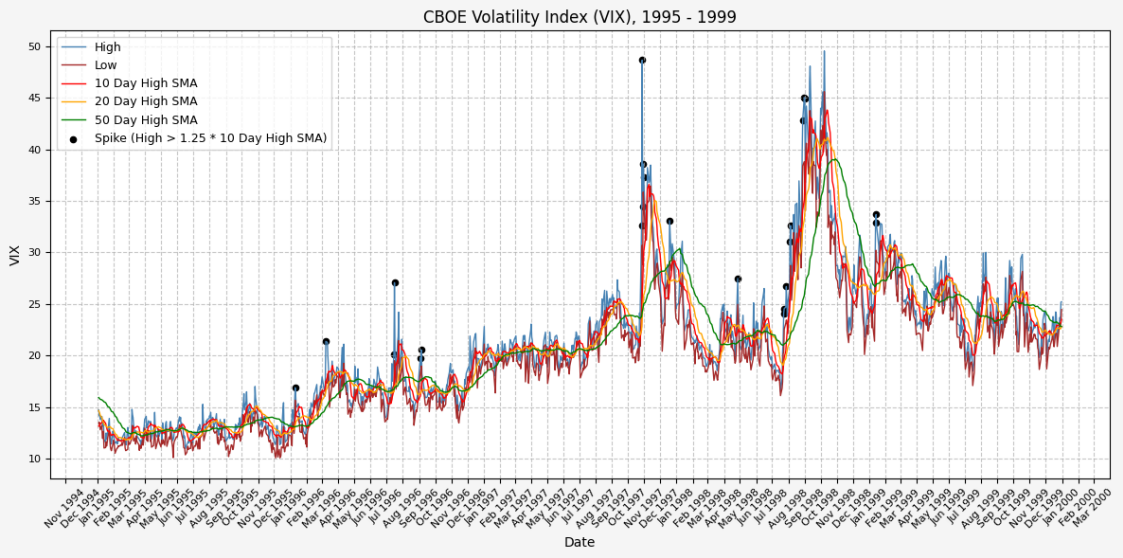
1990 - 1994

[85]:
```
vix_plot('1990', '1994')
```



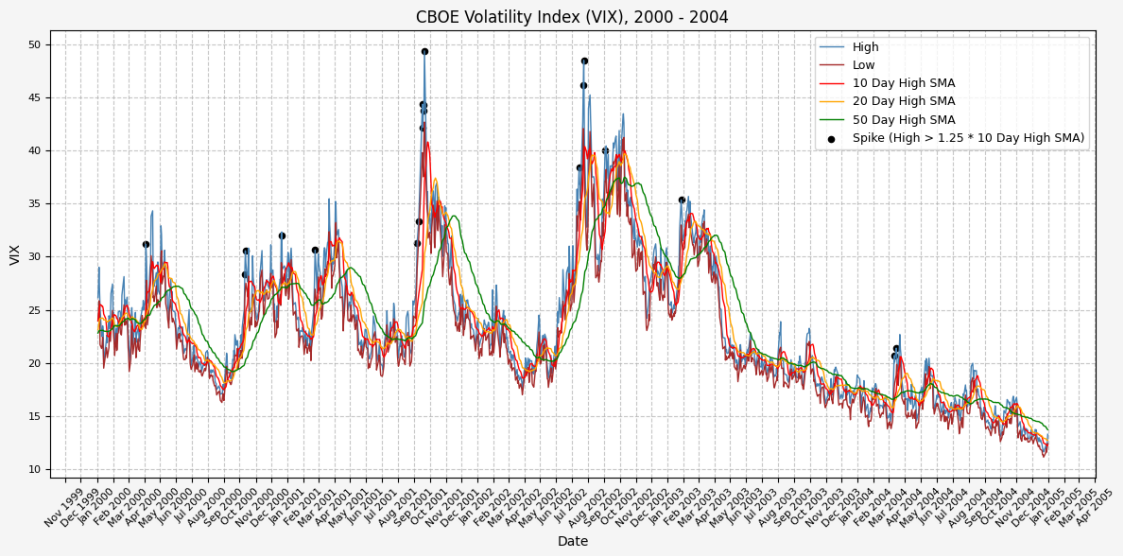
1995 - 1999

[86]:
```
vix_plot('1995', '1999')
```



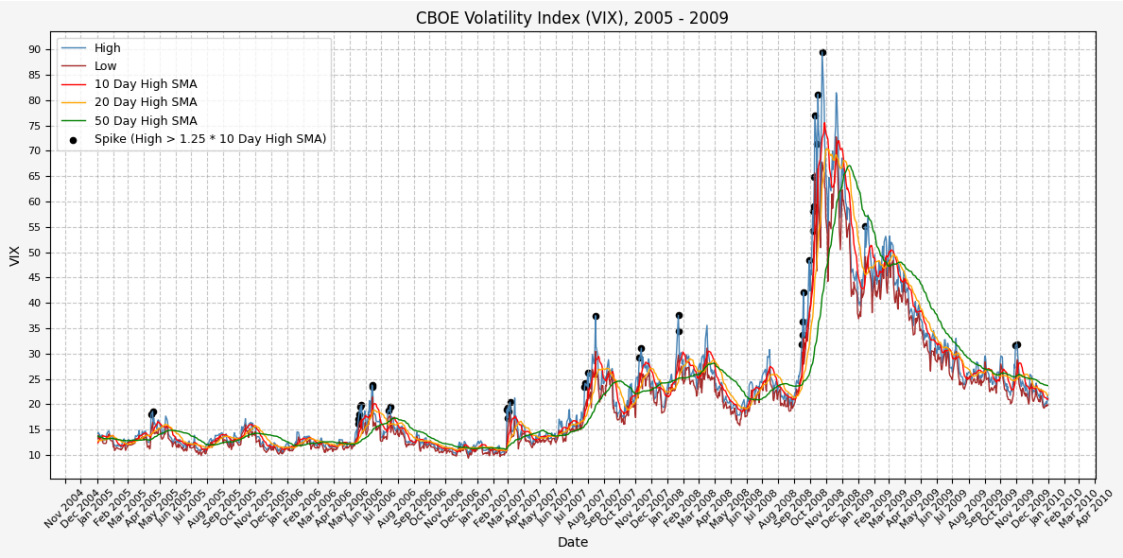
2000 - 2004

[87]:
```
vix_plot('2000', '2004')
```



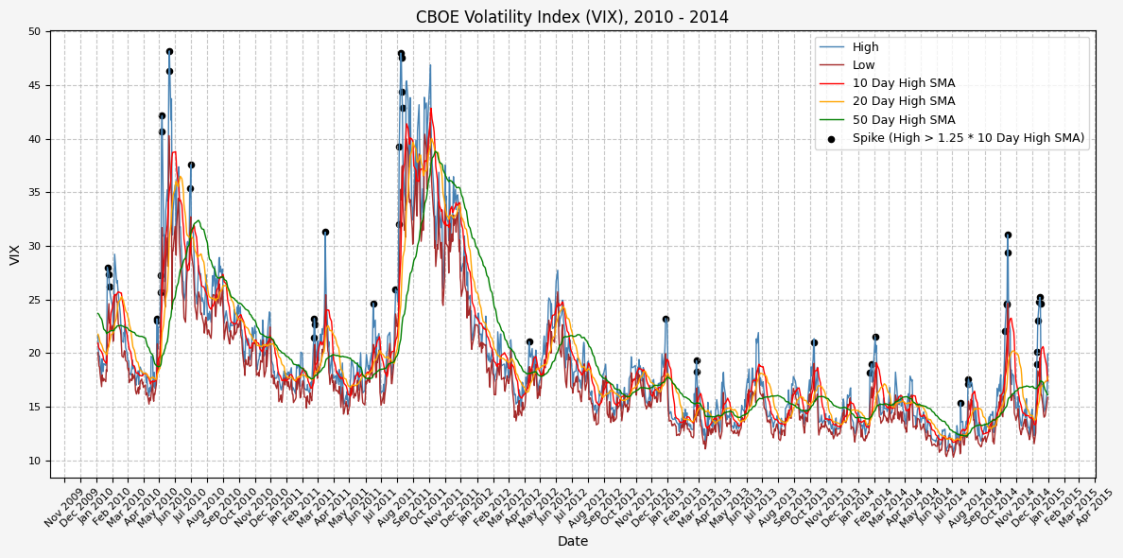
2005 - 2009

[88]:
```
vix_plot('2005', '2009')
```



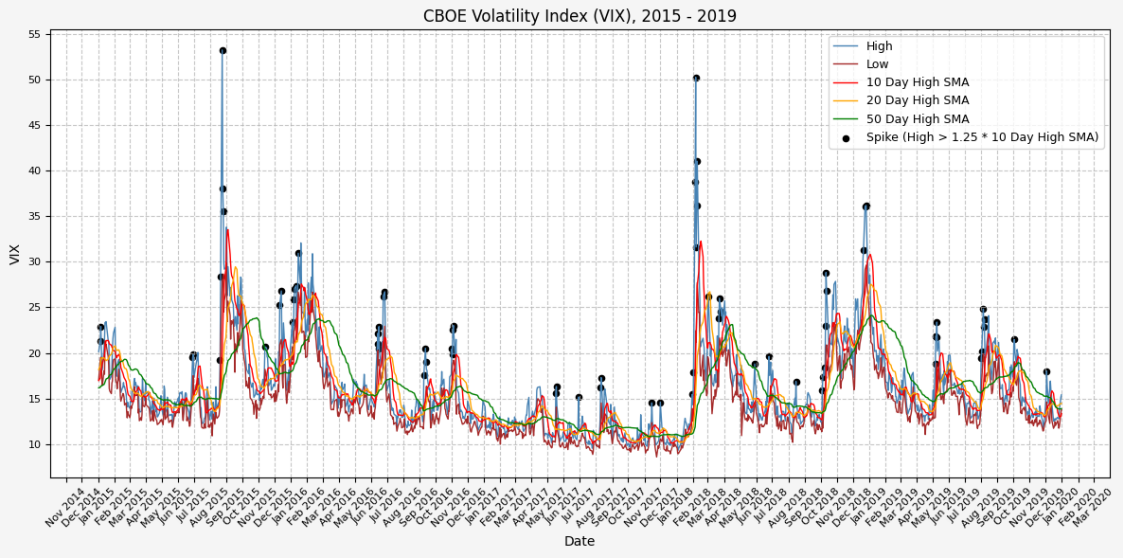
2010 - 2014

[89]:
```
vix_plot('2010', '2014')
```



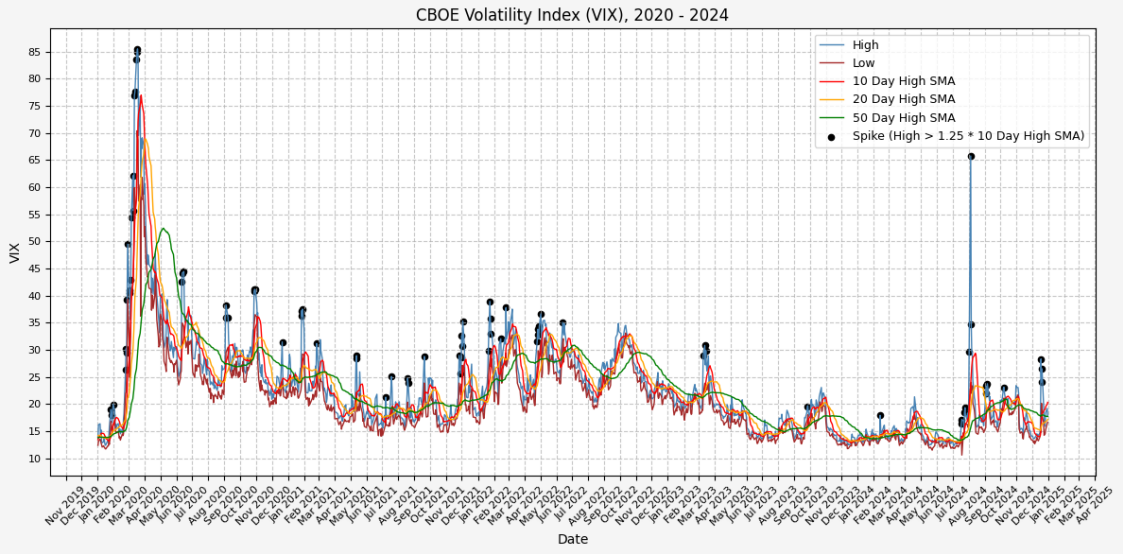
2015 - 2019

[90]:
```
vix_plot('2015', '2019')
```



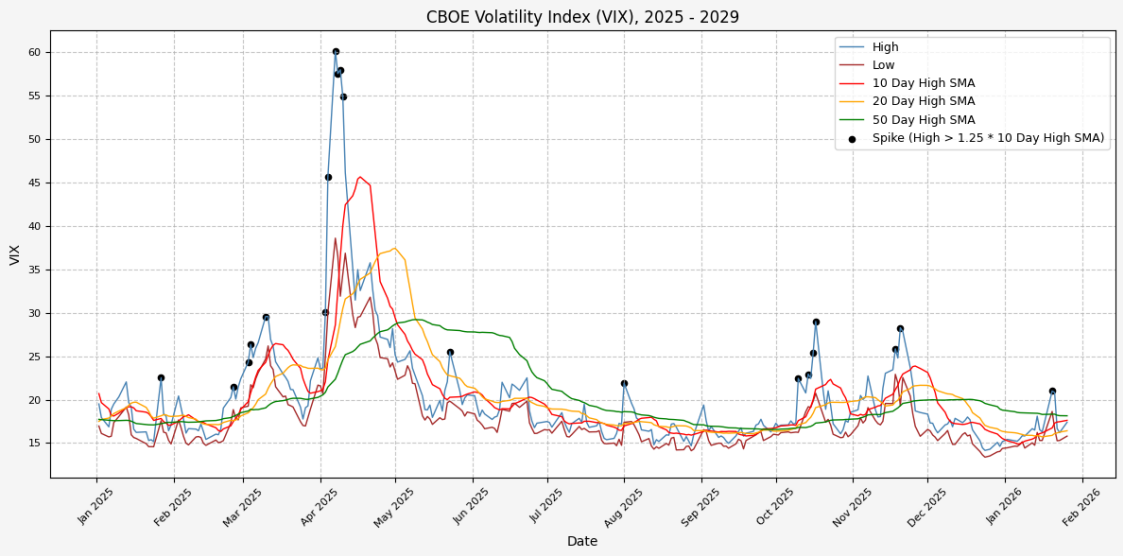
2020 - 2024

[91]:
```
vix_plot('2020', '2024')
```



2025 - Present

[92]:
```
vix_plot('2025', '2029')
```



1.13 Trading History

1.13.1 Trades Executed

[93]:
```
# from schwab_order_history import schwab_order_history
```

[94]:
```
# from datetime import datetime
# import pandas as pd

# # Define your date ranges
# range_2024 = {
#     "from": "2024-01-01T00:00:00.000Z",
#     "to": "2024-12-31T23:59:59.000Z",
# }

# range_2025 = {
#     "from": "2025-01-01T00:00:00.000Z",
#     "to": datetime.utcnow().strftime("%Y-%m-%dT%H:%M:%S.000Z"),
# }

# # Pull both sets of orders
# df_2024 = schwab_order_history(
#     max_results=1000,  # or whatever large number you want
#     from_entered_time=range_2024["from"],
#     to_entered_time=range_2024["to"],
#     account_id=None,  # or pass your specific encrypted account ID
# )

# df_2025 = schwab_order_history(
#     max_results=1000,
#     from_entered_time=range_2025["from"],
#     to_entered_time=range_2025["to"],
#     account_id=None,
# )

# # Combine the two dataframes
# df_all = pd.concat([df_2024, df_2025], ignore_index=True)
```

[95]:
```
# df_2024
```

[96]:
```
# # Filter for symbols that start with "VIX"
# df_vix = df_all[df_all["symbol"].str.startswith("VIX")].copy()
# df_vix = df_vix.sort_values(by=['symbol', 'execution_time'], ascending=[True,␣
 ↪True])
```

[97]:
```
# df_vix
```

1.13.2 Trades Executed

[98]:
```
# Import CSV file of VIX transactions from IRA and Brokerage accounts
vix_transactions_IRA = pd.read_csv(DATA_MANUAL_DIR / "VIX_Transactions_IRA.csv")
vix_transactions_Brokerage = pd.read_excel(DATA_MANUAL_DIR /␣
 ↪"VIX_Transactions_Brokerage.xlsx", sheet_name="VIX_Transactions_Brokerage")
```

[99]:
```
# Combine the two DataFrames
vix_transactions = pd.concat([vix_transactions_IRA,␣
 ↪vix_transactions_Brokerage], ignore_index=True)

# Drop unnecessary columns
vix_transactions.drop(columns = {'Description'}, inplace=True)

# Convert Amount, Price, and Fees & Comm columns to numeric
vix_transactions['Amount'] = vix_transactions['Amount'].replace({'\$': '', ',':␣
 ↪''}, regex=True).astype(float)
vix_transactions['Price'] = vix_transactions['Price'].replace({'\$': '', ',':␣
 ↪''}, regex=True).astype(float)
vix_transactions['Fees & Comm'] = vix_transactions['Fees & Comm'].replace({'\$':
 ↪ '', ',': ''}, regex=True).astype(float)

# Convert Amount column to absolute values
vix_transactions['Amount'] = abs(vix_transactions['Amount'])

# Extract date for option expiration with regex (MM/DD/YYYY)
vix_transactions["Exp_Date"] = vix_transactions["Symbol"].str.extract(r'(\d{2}/
 ↪\d{2}/\d{4})')

# Extract date for option strike price with regex and convert to float
vix_transactions["Strike_Price"] = vix_transactions["Symbol"].str.
 ↪extract(r'(\d{2}\.\d{2})').astype(float)

# Convert expiration date and trade date to datetime
vix_transactions["Exp_Date"] = pd.to_datetime(vix_transactions["Exp_Date"],␣
 ↪format="%m/%d/%Y")
vix_transactions['Date'] = pd.to_datetime(vix_transactions['Date'])

# Rename date to trade date
vix_transactions.rename(columns={'Date': 'Trade_Date'}, inplace=True)

# Sort by Exp_Date, then Strike_Price, then Trade_Date
vix_transactions.sort_values(by=['Exp_Date', 'Strike_Price', 'Trade_Date'],␣
 ↪ascending=[True, True, True], inplace=True)

# Reset index
vix_transactions.reset_index(drop=True, inplace=True)
vix_transactions
```

[99]:

	Trade_Date	Action	Symbol	Quantity	Price	\
0	2024-08-05	Buy to Open	VIX 09/18/2024 34.00 P	1	10.95	
1	2024-08-21	Sell to Close	VIX 09/18/2024 34.00 P	1	17.95	
2	2024-08-05	Buy to Open	VIX 10/16/2024 40.00 P	1	16.35	

```
3  2024-09-18  Sell to Close  VIX 10/16/2024 40.00 P         1  21.54
4  2024-08-07    Buy to Open  VIX 11/20/2024 25.00 P         2   5.90
..        …            …                        …       …    …
59 2025-10-09  Sell to Close  VIX 11/19/2025 20.00 C        10   2.08
60 2025-08-12    Buy to Open  VIX 11/19/2025 21.00 C        10   3.00
61 2025-10-08  Sell to Close  VIX 11/19/2025 21.00 C        10   1.83
62 2025-09-11    Buy to Open  VIX 12/17/2025 17.00 C        10   3.90
63 2025-10-10  Sell to Close  VIX 12/17/2025 17.00 C        10   4.60

    Fees & Comm  Amount  Approx_VIX_Level Comments   Exp_Date  Strike_Price
0          1.08 1096.08             34.33      NaN 2024-09-18         34.00
1          1.08 1793.92             16.50      NaN 2024-09-18         34.00
2          1.08 1636.08             42.71      NaN 2024-10-16         40.00
3          1.08 2152.92             18.85      NaN 2024-10-16         40.00
4          2.16 1182.16             27.11      NaN 2024-11-20         25.00
..          …     …                 …       …         …            …
59        10.81 2069.19               NaN      NaN 2025-11-19         20.00
60        10.81 3010.81             15.17      NaN 2025-11-19         21.00
61         9.31 1820.69               NaN      NaN 2025-11-19         21.00
62        10.81 3910.81               NaN      NaN 2025-12-17         17.00
63        10.81 4589.19               NaN      NaN 2025-12-17         17.00

[64 rows x 11 columns]
```

[100]:
```
vix_transactions_no_exp = vix_transactions.drop(columns=['Exp_Date',␣
↪'Strike_Price'])
vix_transactions_no_exp
```

[100]:
```
   Trade_Date         Action                   Symbol  Quantity  Price  \
0  2024-08-05    Buy to Open  VIX 09/18/2024 34.00 P         1  10.95
1  2024-08-21  Sell to Close  VIX 09/18/2024 34.00 P         1  17.95
2  2024-08-05    Buy to Open  VIX 10/16/2024 40.00 P         1  16.35
3  2024-09-18  Sell to Close  VIX 10/16/2024 40.00 P         1  21.54
4  2024-08-07    Buy to Open  VIX 11/20/2024 25.00 P         2   5.90
..        …            …                        …       …    …
59 2025-10-09  Sell to Close  VIX 11/19/2025 20.00 C        10   2.08
60 2025-08-12    Buy to Open  VIX 11/19/2025 21.00 C        10   3.00
61 2025-10-08  Sell to Close  VIX 11/19/2025 21.00 C        10   1.83
62 2025-09-11    Buy to Open  VIX 12/17/2025 17.00 C        10   3.90
63 2025-10-10  Sell to Close  VIX 12/17/2025 17.00 C        10   4.60

    Fees & Comm  Amount  Approx_VIX_Level Comments
0          1.08 1096.08             34.33      NaN
1          1.08 1793.92             16.50      NaN
2          1.08 1636.08             42.71      NaN
3          1.08 2152.92             18.85      NaN
4          2.16 1182.16             27.11      NaN
```

```
..          …     …                 …       …
59        10.81 2069.19               NaN     NaN
60        10.81 3010.81             15.17     NaN
61         9.31 1820.69               NaN     NaN
62        10.81 3910.81               NaN     NaN
63        10.81 4589.19               NaN     NaN

[64 rows x 9 columns]
```

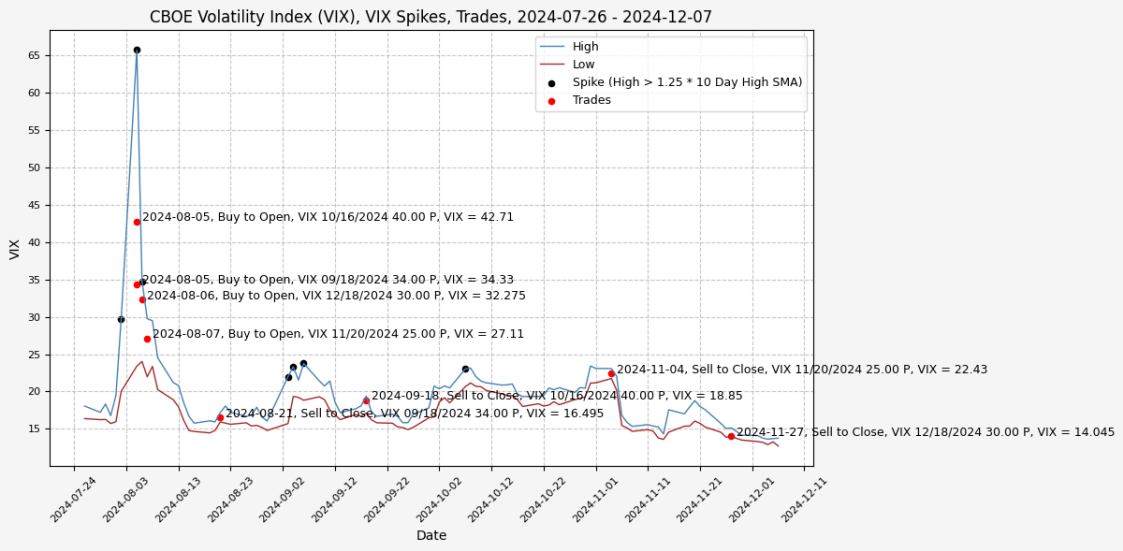
[101]:
```
# Copy this <!-- INSERT_10_Trades_Executed_HERE --> to index_temp.md
export_track_md_deps(dep_file=dep_file, md_filename="10_Trades_Executed.md",␣
 ↪content=vix_transactions_no_exp.to_markdown(index=False, floatfmt=".2f"))
```

```
Exported and tracked: 10_Trades_Executed.md
```

Volatility In August 2024

[102]:
```
# Variables to be modifed
esd = "2024-09-18" # Expiration Start Date
eed = "2024-12-18" # Expiration End Date
tsd = "2024-08-05" # Trade Start Date
ted = "2024-11-27" # Trade End Date
index_number = "11"
x_tick_spacing = 10
y_tick_spacing = 5

################################################
## Do not modify the code below this line ##
################################################

trades, closed_pos, open_pos, per_pnl, pnl, tot_opened_pos_mkt_val,␣
 ↪tot_closed_pos_mkt_val = calc_vix_trade_pnl(
    transaction_df=vix_transactions,
    exp_start_date=esd,
    exp_end_date=eed,
    trade_start_date=tsd,
    trade_end_date=ted,
)

# Convert to datetime objects
tsd_dt = datetime.strptime(tsd, "%Y-%m-%d")
ted_dt = datetime.strptime(ted, "%Y-%m-%d")

# Adjust the plot start and end dates
plot_start = tsd_dt - timedelta(days=10)
plot_end = ted_dt + timedelta(days=10)

plot_vix_with_trades(
```

```
    vix_price_df=vix,
    trades_df=trades,
    plot_start_date=plot_start.strftime("%Y-%m-%d"),
    plot_end_date=plot_end.strftime("%Y-%m-%d"),
    x_tick_spacing=x_tick_spacing,
    y_tick_spacing=y_tick_spacing,
    index_number=index_number,
    export_plot=True,
)

print(f"<!-- INSERT_{index_number}_Closed_Positions_HERE -->")
print(f"<!-- INSERT_{index_number}_Open_Positions_HERE -->")
print(f"<!-- INSERT_{index_number}_Total_Opened_Position_Market_Value_HERE -->")
print(f"<!-- INSERT_{index_number}_Total_Closed_Position_Market_Value_HERE -->")
print(f"<!-- INSERT_{index_number}_PnL_HERE -->")
print(f"<!-- INSERT_{index_number}_Percent_PnL_HERE -->")
export_track_md_deps(dep_file=dep_file,␣
 ↪md_filename=f"{index_number}_Closed_Positions.md", content=closed_pos.
 ↪to_markdown(index=False, floatfmt=".2f"))
export_track_md_deps(dep_file=dep_file,␣
 ↪md_filename=f"{index_number}_Open_Positions.md", content=open_pos.
 ↪to_markdown(index=False, floatfmt=".2f"))
export_track_md_deps(dep_file=dep_file,␣
 ↪md_filename=f"{index_number}_Total_Opened_Position_Market_Value.txt",␣
 ↪content=tot_opened_pos_mkt_val)
export_track_md_deps(dep_file=dep_file,␣
 ↪md_filename=f"{index_number}_Total_Closed_Position_Market_Value.txt",␣
 ↪content=tot_closed_pos_mkt_val)
export_track_md_deps(dep_file=dep_file, md_filename=f"{index_number}_PnL.txt",␣
 ↪content=pnl)
export_track_md_deps(dep_file=dep_file,␣
 ↪md_filename=f"{index_number}_Percent_PnL.txt", content=per_pnl)
```



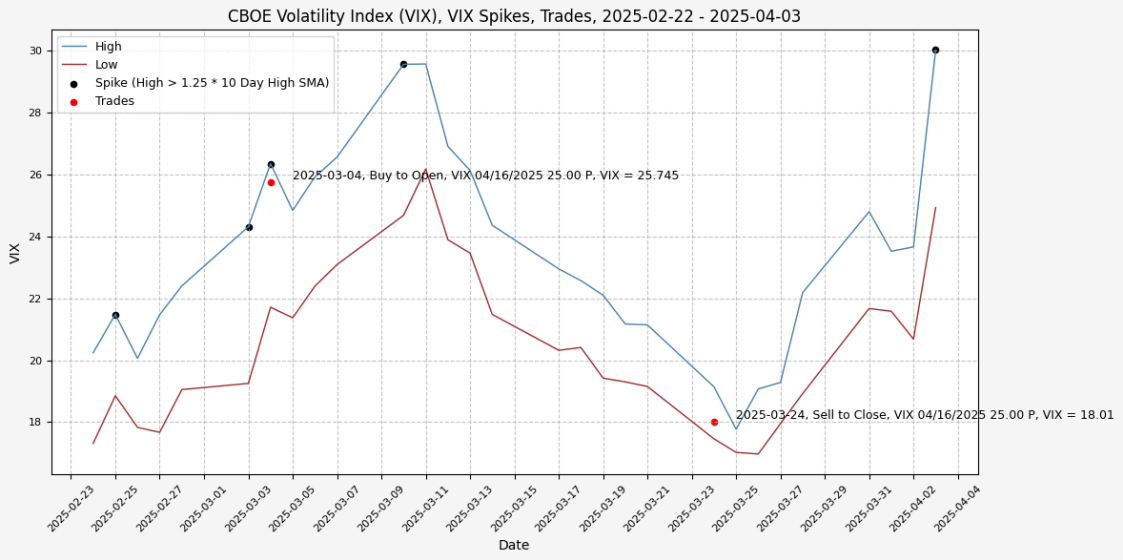

```
<!-- INSERT_11_Closed_Positions_HERE -->
<!-- INSERT_11_Open_Positions_HERE -->
<!-- INSERT_11_Total_Opened_Position_Market_Value_HERE -->
<!-- INSERT_11_Total_Closed_Position_Market_Value_HERE -->
<!-- INSERT_11_PnL_HERE -->
<!-- INSERT_11_Percent_PnL_HERE -->
  Exported and tracked: 11_Closed_Positions.md
  Exported and tracked: 11_Open_Positions.md
  Exported and tracked: 11_Total_Opened_Position_Market_Value.txt
  Exported and tracked: 11_Total_Closed_Position_Market_Value.txt
  Exported and tracked: 11_PnL.txt
  Exported and tracked: 11_Percent_PnL.txt
```

Volatility In March 2025

[103]:
```
# Variables to be modifed
esd = "2025-04-16" # Expiration Start Date
eed = "2025-04-16" # Expiration End Date
tsd = "2025-03-04" # Trade Start Date
ted = "2025-03-24" # Trade End Date
index_number = "12"
x_tick_spacing = 2
y_tick_spacing = 2

###############################################
## Do not modify the code below this line ##
###############################################

trades, closed_pos, open_pos, per_pnl, pnl, tot_opened_pos_mkt_val,␣
 ↪tot_closed_pos_mkt_val = calc_vix_trade_pnl(
```

```
    transaction_df=vix_transactions,
    exp_start_date=esd,
    exp_end_date=eed,
    trade_start_date=tsd,
    trade_end_date=ted,
)

# Convert to datetime objects
tsd_dt = datetime.strptime(tsd, "%Y-%m-%d")
ted_dt = datetime.strptime(ted, "%Y-%m-%d")

# Adjust the plot start and end dates
plot_start = tsd_dt - timedelta(days=10)
plot_end = ted_dt + timedelta(days=10)

plot_vix_with_trades(
    vix_price_df=vix,
    trades_df=trades,
    plot_start_date=plot_start.strftime("%Y-%m-%d"),
    plot_end_date=plot_end.strftime("%Y-%m-%d"),
    x_tick_spacing=x_tick_spacing,
    y_tick_spacing=y_tick_spacing,
    index_number=index_number,
    export_plot=True,
)

print(f"<!-- INSERT_{index_number}_Closed_Positions_HERE -->")
print(f"<!-- INSERT_{index_number}_Open_Positions_HERE -->")
print(f"<!-- INSERT_{index_number}_Total_Opened_Position_Market_Value_HERE -->")
print(f"<!-- INSERT_{index_number}_Total_Closed_Position_Market_Value_HERE -->")
print(f"<!-- INSERT_{index_number}_PnL_HERE -->")
print(f"<!-- INSERT_{index_number}_Percent_PnL_HERE -->")
export_track_md_deps(dep_file=dep_file,␣
 ↪md_filename=f"{index_number}_Closed_Positions.md", content=closed_pos.
 ↪to_markdown(index=False, floatfmt=".2f"))
export_track_md_deps(dep_file=dep_file,␣
 ↪md_filename=f"{index_number}_Open_Positions.md", content=open_pos.
 ↪to_markdown(index=False, floatfmt=".2f"))
export_track_md_deps(dep_file=dep_file,␣
 ↪md_filename=f"{index_number}_Total_Opened_Position_Market_Value.txt",␣
 ↪content=tot_opened_pos_mkt_val)
export_track_md_deps(dep_file=dep_file,␣
 ↪md_filename=f"{index_number}_Total_Closed_Position_Market_Value.txt",␣
 ↪content=tot_closed_pos_mkt_val)
export_track_md_deps(dep_file=dep_file, md_filename=f"{index_number}_PnL.txt",␣
 ↪content=pnl)
```

```
export_track_md_deps(dep_file=dep_file,␣
 ↪md_filename=f"{index_number}_Percent_PnL.txt", content=per_pnl)
```



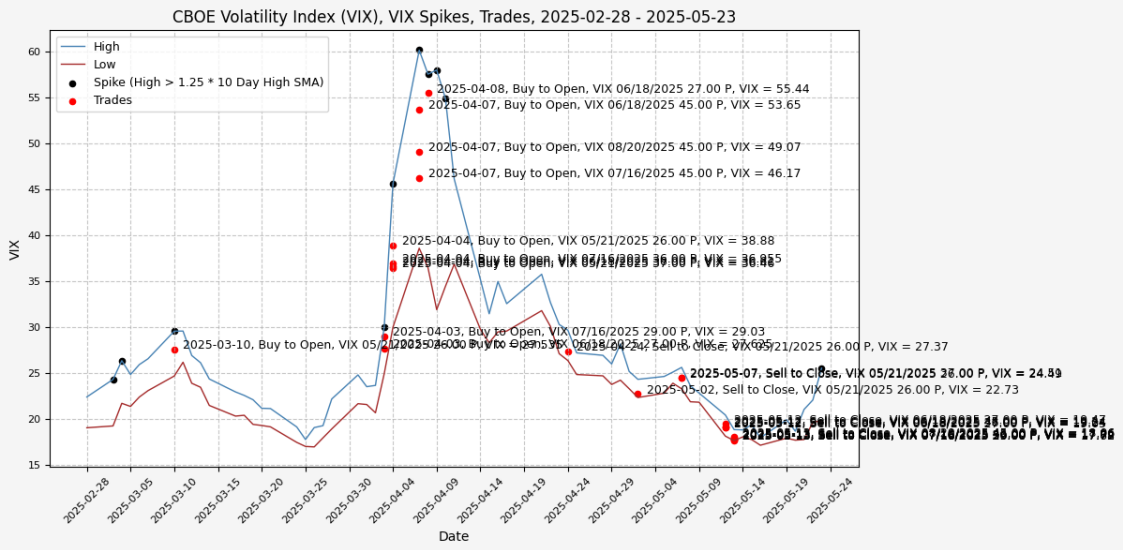

```
<!-- INSERT_12_Closed_Positions_HERE -->
<!-- INSERT_12_Open_Positions_HERE -->
<!-- INSERT_12_Total_Opened_Position_Market_Value_HERE -->
<!-- INSERT_12_Total_Closed_Position_Market_Value_HERE -->
<!-- INSERT_12_PnL_HERE -->
<!-- INSERT_12_Percent_PnL_HERE -->
  Exported and tracked: 12_Closed_Positions.md
  Exported and tracked: 12_Open_Positions.md
  Exported and tracked: 12_Total_Opened_Position_Market_Value.txt
  Exported and tracked: 12_Total_Closed_Position_Market_Value.txt
  Exported and tracked: 12_PnL.txt
  Exported and tracked: 12_Percent_PnL.txt
```

Volatility In April 2025

[104]:
```
# Variables to be modifed
esd = "2025-05-21" # Expiration Start Date
eed = "2025-08-20" # Expiration End Date
tsd = "2025-03-10" # Trade Start Date
ted = "2025-05-13" # Trade End Date
index_number = "13"
x_tick_spacing = 5
y_tick_spacing = 5

##############################################
## Do not modify the code below this line ##
```

```
##############################################

trades, closed_pos, open_pos, per_pnl, pnl, tot_opened_pos_mkt_val,␣
 ↪tot_closed_pos_mkt_val = calc_vix_trade_pnl(
    transaction_df=vix_transactions,
    exp_start_date=esd,
    exp_end_date=eed,
    trade_start_date=tsd,
    trade_end_date=ted,
)

# Convert to datetime objects
tsd_dt = datetime.strptime(tsd, "%Y-%m-%d")
ted_dt = datetime.strptime(ted, "%Y-%m-%d")

# Adjust the plot start and end dates
plot_start = tsd_dt - timedelta(days=10)
plot_end = ted_dt + timedelta(days=10)

plot_vix_with_trades(
    vix_price_df=vix,
    trades_df=trades,
    plot_start_date=plot_start.strftime("%Y-%m-%d"),
    plot_end_date=plot_end.strftime("%Y-%m-%d"),
    x_tick_spacing=x_tick_spacing,
    y_tick_spacing=y_tick_spacing,
    index_number=index_number,
    export_plot=True,
)

print(f"<!-- INSERT_{index_number}_Closed_Positions_HERE -->")
print(f"<!-- INSERT_{index_number}_Open_Positions_HERE -->")
print(f"<!-- INSERT_{index_number}_Total_Opened_Position_Market_Value_HERE -->")
print(f"<!-- INSERT_{index_number}_Total_Closed_Position_Market_Value_HERE -->")
print(f"<!-- INSERT_{index_number}_PnL_HERE -->")
print(f"<!-- INSERT_{index_number}_Percent_PnL_HERE -->")
export_track_md_deps(dep_file=dep_file,␣
 ↪md_filename=f"{index_number}_Closed_Positions.md", content=closed_pos.
 ↪to_markdown(index=False, floatfmt=".2f"))
export_track_md_deps(dep_file=dep_file,␣
 ↪md_filename=f"{index_number}_Open_Positions.md", content=open_pos.
 ↪to_markdown(index=False, floatfmt=".2f"))
export_track_md_deps(dep_file=dep_file,␣
 ↪md_filename=f"{index_number}_Total_Opened_Position_Market_Value.txt",␣
 ↪content=tot_opened_pos_mkt_val)
```

```
export_track_md_deps(dep_file=dep_file,␣
 ↪md_filename=f"{index_number}_Total_Closed_Position_Market_Value.txt",␣
 ↪content=tot_closed_pos_mkt_val)
export_track_md_deps(dep_file=dep_file, md_filename=f"{index_number}_PnL.txt",␣
 ↪content=pnl)
export_track_md_deps(dep_file=dep_file,␣
 ↪md_filename=f"{index_number}_Percent_PnL.txt", content=per_pnl)
```



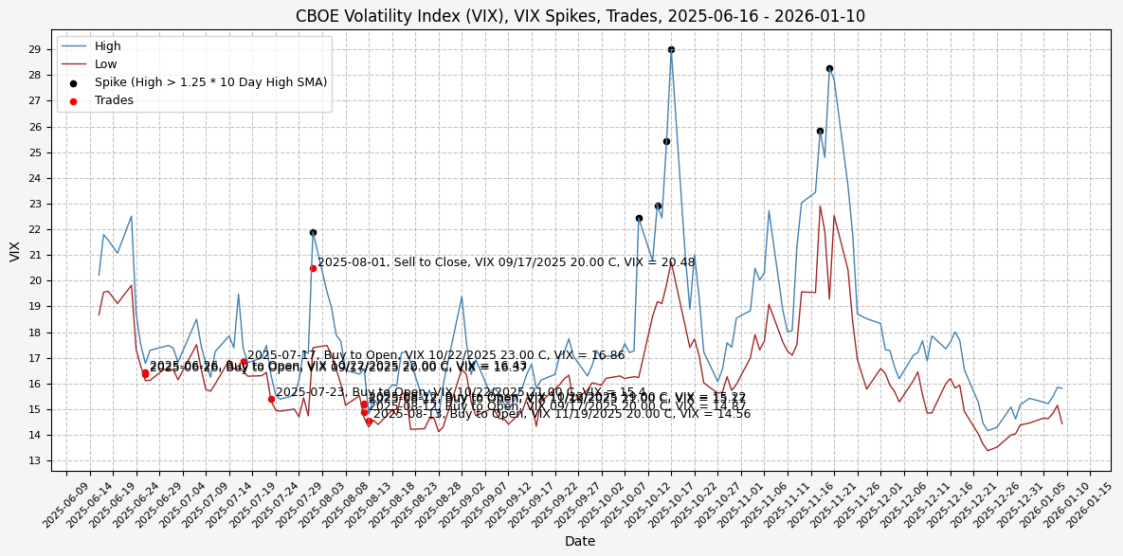

```
<!-- INSERT_13_Closed_Positions_HERE -->
<!-- INSERT_13_Open_Positions_HERE -->
<!-- INSERT_13_Total_Opened_Position_Market_Value_HERE -->
<!-- INSERT_13_Total_Closed_Position_Market_Value_HERE -->
<!-- INSERT_13_PnL_HERE -->
<!-- INSERT_13_Percent_PnL_HERE -->
  Exported and tracked: 13_Closed_Positions.md
  Exported and tracked: 13_Open_Positions.md
  Exported and tracked: 13_Total_Opened_Position_Market_Value.txt
  Exported and tracked: 13_Total_Closed_Position_Market_Value.txt
  Exported and tracked: 13_PnL.txt
  Exported and tracked: 13_Percent_PnL.txt
```

Low Volatility In June, July, August, September, October, November 2025

[105]:
```
# Variables to be modifed
esd = "2025-09-17" # Expiration Start Date
eed = "2025-12-31" # Expiration End Date
tsd = "2025-06-26" # Trade Start Date
ted = "2025-12-31"  # Trade End Date
index_number = "14"
```

```
x_tick_spacing = 5
y_tick_spacing = 1

##############################################
## Do not modify the code below this line ##
##############################################

trades, closed_pos, open_pos, per_pnl, pnl, tot_opened_pos_mkt_val,␣
 ↪tot_closed_pos_mkt_val = calc_vix_trade_pnl(
    transaction_df=vix_transactions,
    exp_start_date=esd,
    exp_end_date=eed,
    trade_start_date=tsd,
    trade_end_date=ted,
)

# Convert to datetime objects
tsd_dt = datetime.strptime(tsd, "%Y-%m-%d")
ted_dt = datetime.strptime(ted, "%Y-%m-%d")

# Adjust the plot start and end dates
plot_start = tsd_dt - timedelta(days=10)
plot_end = ted_dt + timedelta(days=10)

plot_vix_with_trades(
    vix_price_df=vix,
    trades_df=trades,
    plot_start_date=plot_start.strftime("%Y-%m-%d"),
    plot_end_date=plot_end.strftime("%Y-%m-%d"),
    x_tick_spacing=x_tick_spacing,
    y_tick_spacing=y_tick_spacing,
    index_number=index_number,
    export_plot=True,
)

print(f"<!-- INSERT_{index_number}_Closed_Positions_HERE -->")
print(f"<!-- INSERT_{index_number}_Open_Positions_HERE -->")
print(f"<!-- INSERT_{index_number}_Total_Opened_Position_Market_Value_HERE -->")
print(f"<!-- INSERT_{index_number}_Total_Closed_Position_Market_Value_HERE -->")
print(f"<!-- INSERT_{index_number}_PnL_HERE -->")
print(f"<!-- INSERT_{index_number}_Percent_PnL_HERE -->")
export_track_md_deps(dep_file=dep_file,␣
 ↪md_filename=f"{index_number}_Closed_Positions.md", content=closed_pos.
 ↪to_markdown(index=False, floatfmt=".2f"))
export_track_md_deps(dep_file=dep_file,␣
 ↪md_filename=f"{index_number}_Open_Positions.md", content=open_pos.
 ↪to_markdown(index=False, floatfmt=".2f"))
```

```
export_track_md_deps(dep_file=dep_file,␣
 ↪md_filename=f"{index_number}_Total_Opened_Position_Market_Value.txt",␣
 ↪content=tot_opened_pos_mkt_val)
export_track_md_deps(dep_file=dep_file,␣
 ↪md_filename=f"{index_number}_Total_Closed_Position_Market_Value.txt",␣
 ↪content=tot_closed_pos_mkt_val)
export_track_md_deps(dep_file=dep_file, md_filename=f"{index_number}_PnL.txt",␣
 ↪content=pnl)
export_track_md_deps(dep_file=dep_file,␣
 ↪md_filename=f"{index_number}_Percent_PnL.txt", content=per_pnl)
```




```
<!-- INSERT_14_Closed_Positions_HERE -->
<!-- INSERT_14_Open_Positions_HERE -->
<!-- INSERT_14_Total_Opened_Position_Market_Value_HERE -->
<!-- INSERT_14_Total_Closed_Position_Market_Value_HERE -->
<!-- INSERT_14_PnL_HERE -->
<!-- INSERT_14_Percent_PnL_HERE -->
  Exported and tracked: 14_Closed_Positions.md
  Exported and tracked: 14_Open_Positions.md
  Exported and tracked: 14_Total_Opened_Position_Market_Value.txt
  Exported and tracked: 14_Total_Closed_Position_Market_Value.txt
  Exported and tracked: 14_PnL.txt
  Exported and tracked: 14_Percent_PnL.txt
```

Complete Trade History

[106]:
```
# Variables to be modifed
esd = None
eed = None
```

```
tsd = None
ted = None
index_number = "99"

###########################################
## Do not modify the code below this line ##
###########################################

trades, closed_pos, open_pos, per_pnl, pnl, tot_opened_pos_mkt_val,␣
 ↪tot_closed_pos_mkt_val = calc_vix_trade_pnl(
    transaction_df=vix_transactions,
    exp_start_date=esd,
    exp_end_date=eed,
    trade_start_date=tsd,
    trade_end_date=ted,
)

print(f"<!-- INSERT_{index_number}_Closed_Positions_HERE -->")
print(f"<!-- INSERT_{index_number}_Open_Positions_HERE -->")
print(f"<!-- INSERT_{index_number}_Total_Opened_Position_Market_Value_HERE -->")
print(f"<!-- INSERT_{index_number}_Total_Closed_Position_Market_Value_HERE -->")
print(f"<!-- INSERT_{index_number}_PnL_HERE -->")
print(f"<!-- INSERT_{index_number}_Percent_PnL_HERE -->")
export_track_md_deps(dep_file=dep_file,␣
 ↪md_filename=f"{index_number}_Closed_Positions.md", content=closed_pos.
 ↪to_markdown(index=False, floatfmt=".2f"))
export_track_md_deps(dep_file=dep_file,␣
 ↪md_filename=f"{index_number}_Open_Positions.md", content=open_pos.
 ↪to_markdown(index=False, floatfmt=".2f"))
export_track_md_deps(dep_file=dep_file,␣
 ↪md_filename=f"{index_number}_Total_Opened_Position_Market_Value.txt",␣
 ↪content=tot_opened_pos_mkt_val)
export_track_md_deps(dep_file=dep_file,␣
 ↪md_filename=f"{index_number}_Total_Closed_Position_Market_Value.txt",␣
 ↪content=tot_closed_pos_mkt_val)
export_track_md_deps(dep_file=dep_file, md_filename=f"{index_number}_PnL.txt",␣
 ↪content=pnl)
export_track_md_deps(dep_file=dep_file,␣
 ↪md_filename=f"{index_number}_Percent_PnL.txt", content=per_pnl)
```

```
<!-- INSERT_99_Closed_Positions_HERE -->
<!-- INSERT_99_Open_Positions_HERE -->
<!-- INSERT_99_Total_Opened_Position_Market_Value_HERE -->
<!-- INSERT_99_Total_Closed_Position_Market_Value_HERE -->
<!-- INSERT_99_PnL_HERE -->
<!-- INSERT_99_Percent_PnL_HERE -->
  Exported and tracked: 99_Closed_Positions.md
```

```
Exported and tracked: 99_Open_Positions.md
Exported and tracked: 99_Total_Opened_Position_Market_Value.txt
Exported and tracked: 99_Total_Closed_Position_Market_Value.txt
Exported and tracked: 99_PnL.txt
Exported and tracked: 99_Percent_PnL.txt
```

[ ]: