VIX CALCULATION

The Volatility Index (VIX),measures 30-day expected volatility of the S&P500 index. Unlike conventional stock indexes, the VIX uses the prices of options to quantify anticipated market volatility. Part 1 of this project outlines a detailed procedure for calculating the VIX value for the S&P500 on January 2, 2015, following the formula and methodology specified in the VIX white paper.

The VIX Calculation

The process of calculating the VIX involves several steps. The primary steps are as follows:

- Calculating the Mid-Quote price for each stike
- Computing strike price contributions
- Volatility Calculation for Near-Term and Next-Term Options
- Calculating the 30-day weighted average variance by combining the variances of near-term and next-term options.
- Deriving the VIX by taking the square root of the average variance and multiplying by 100.

The generalized formula used for calculating the VIX is given by:

$$\sigma^2 = \frac{2}{T} \sum_i \frac{\Delta K_i}{K_i^2} e^{RT} Q(K_i) - \frac{1}{T} \left(\frac{F}{K_0} - 1 \right)^2$$

Where:

- σ is the volatility.
- T is the time to expiration in years.
- F is the forward index level derived from option prices.
- K_0 is the first strike price below the forward index level.
- K_i is the strike price of the ith out-of-the-money option.
- ΔK_i is the interval between strike prices.
- R is the risk-free interest rate.
- $Q(K_i)$ is the mid-quote price for each option.

Data Selection and Filtering

Following the VIX formula provided in the VIX white paper, we have choosen the options data from the spreadsheet provided to find the VIX value of S&P500 on January 2, 2015. Later, the SAS codes generated have been made generic and applied to other dates.

```
/* define the date */
%let date = '02jan2015'd;

/* import the csv file into a sas dataset */
proc import datafile="/home/option.csv"
    out=option
    dbms=csv
    replace;
    getnames=yes;
run;

/* filter data for the date */
data filtered_data;
    set option;
    if date = &date;
run;
```

The filtered data is given in table below:

01/02/15	15	1965	98.55	2058.2	0.0015	5.15
01/02/15	15	1970	93.95	2058.2	0.0015	5.55
01/02/15	15	1975	89.4	2058.2	0.0015	6
01/02/15	15	1980	85.05	2058.2	0.0015	6.45
01/02/15	15	1985	80.3	2058.2	0.0015	6.9
01/02/15	15	1990	75.95	2058.2	0.0015	7.5
01/02/15	15	1995	71.6	2058.2	0.0015	8.05
01/02/15	15	2000	67.35	2058.2	0.0015	8.65
01/02/15	15	2005	63.05	2058.2	0.0015	9.35
01/02/15	15	2010	58.75	2058.2	0.0015	10.05
01/02/15	15	2015	54.55	2058.2	0.0015	10.95
01/02/15	15	2020	50.4	2058.2	0.0015	11.8
01/02/15	15	2025	46.35	2058.2	0.0015	12.75
01/02/15	15	2030	42.45	2058.2	0.0015	13.85
01/02/15	15	2035	38.6	2058.2	0.0015	14.95
01/02/15	15	2040	34.85	2058.2	0.0015	16.25
01/02/15	15	2045	31.1	2058.2	0.0015	17.65
01/02/15	15	2050	27.15	2058.2	0.0015	19.15
01/02/15	15	2055	24.3	2058.2	0.0015	20.8
01/02/15	15	2060	20.85	2058.2	0.0015	22.65
01/02/15	15	2065	17.95	2058.2	0.0015	24.7
01/02/15	15	2070	15.25	2058.2	0.0015	26.9
01/02/15	15	2075	12.65	2058.2	0.0015	29.2
01/02/15	15	2080	10.2	2058.2	0.0015	31.9
01/02/15	15	2085	8.25	2058.2	0.0015	34.8
01/02/15	15	2090	6.45	2058.2	0.0015	37.85
01/02/15	15	2095	4.95	2058.2	0.0015	41.3
01/02/15	15	2100	3.7	2058.2	0.0015	45.2
01/02/15	15	2105	2.75	2058.2	0.0015	49.3
01/02/15	15	2110	1.975	2058.2	0.0015	53.6
01/02/15	35	1975	98.55	2058.2	0.0019	16.7
01/02/15	35	1980	94.25	2058.2	0.0019	17.45
01/02/15	35	1985	90.05	2058.2	0.0019	18.25
01/02/15	35	1990	85.9	2058.2	0.0019	19.1
01/02/15	35	1995	81.75	2058.2	0.0019	20
01/02/15	35	2000	77.75	2058.2	0.0019	21
01/02/15	35	2005	73.6	2058.2	0.0019	22
01/02/15	35	2010	69.7	2058.2	0.0019	22.95
01/02/15	35	2015	65.75	2058.2	0.0019	24.05
01/02/15	35	2020	61.85	2058.2	0.0019	25.25
01/02/15	35	2025	58.15	2058.2	0.0019	26.45
01/02/15	35	2030	54.4	2058.2	0.0019	27.7
01/02/15	35	2035	50.85	2058.2	0.0019	29.1
01/02/15	35	2040	47.35	2058.2	0.0019	30.55
01/02/15	35	2045	43.9	2058.2	0.0019	32.05
01/02/15	35	2050	40.5	2058.2	0.0019	33.75
01/02/15	35	2055	37.3	2058.2	0.0019	35.45
01/02/15	35	2060	34.1	2058.2	0.0019	37.3
01/02/15	35	2065	31.15	2058.2	0.0019	39.25
01/02/15	35	2070	28.15	2058.2	0.0019	41.4
01/02/15	35	2075	25.4	2058.2	0.0019	43.6
01/02/15	35	2080	22.75	2058.2	0.0019	46
01/02/15	35	2085	20.3	2058.2	0.0019	48.5
01/02/15	35	2090	18	2058.2	0.0019	51.1
01/02/15	35	2095	15.8	2058.2	0.0019	54.05
01/02/15	35	2100	13.75	2058.2	0.0019	56.95
01/02/15	35	2105	11.85	2058.2	0.0019	60.05
01/02/15	35	2110	10.2	2058.2	0.0019	63.4
01/02/15	35	2115	8.65	2058.2	0.0019	66.95
01/02/15	35	2120	7.35	2058.2	0.0019	70.5
01/02/15	35	2125	6.15	2058.2	0.0019	74.3
01/02/15	35	2130	5.15	2058.2	0.0019	78.25
01/02/15	35	2135	4.25	2058.2	0.0019	82.35
01/02/15	35	2140	3.5	2058.2	0.0019	86.65
01/02/15	35	2145	2.8	2058.2	0.0019	91
01/02/15	35	2150	2.25	2058.2	0.0019	95.3
01/02/15	35	2155	1.925	2058.2	0.0019	99.85

Figure 1: Index data on January 2, 2015

STEP 1: Mid-quote price calculation

From the filtered data we have calculated the mid-quote price for each strike price. This can be done in the following steps:

Calculating the the time to expiration (T) in years for near and next terms

It can be seen from the filtered data that there are 2 sets τ values, 15 and 35. The options with $\tau = 15$ is the near term options and the ones with τ= 35 is the next term options. That is options dated January 2, 2015, either mature in 15 calendar days (near-term options) or 35 calendar days (next-term options).

On examining the other dates date we can see that all the near term τ values are less than 30 and next terms have τ values greater than 30. Thus for the ease of making the code generic we have set 30 as a threshold value. Any options with τ less than 30 is near term and the rest next term.

```
do i = 1 to nrow(options);
    read all var {call_option_price} into c where(date=(date[i]) & tau=(options[i, 'tau']));
    read all var {put_option_price} into p where(date=(date[i]) & tau=(options[i, 'tau']));

  read all var {tau} into tau
        where(date=(date[i]));
  if min(tau) <= 30
  then
        near_date = max(tau[loc(tau <= 30)]);
    else
      near_date = min(tau);
   next_date = min(tau[loc(tau > near_date)]);
   t1 = near_date/365; /*convert the time from days to years by dividing by 365*/
   t2 = next_date/365;
   exp[i, 1] = near_date;
   exp[i, 2] = next_date;
   exp[i, 3] = t1;
   exp[i, 4] = t2;

end;

print t1 t2 ;
```

t1	t2
0.0410959	0.0958904

Figure 2: Time to expiration (T) in years for near and next terms

T1 is the Time to expiration of near term options which is equal to 0.0410959 years and T2 is the Time to expiration of next term options which is equal to 0.0958904 years

Calculating the absolute difference between the call and put options

```
diff = abs(options[,'c'] - options[,'p']);
print diff;
```

tau	K	call_option_price	put_option_price	diff
15	1965	98.55	5.15	93.4
15	1970	93.95	5.55	88.4
15	1975	89.4	6	83.4
15	1980	85.05	6.45	78.6
15	1985	80.3	6.9	73.4
15	1990	75.95	7.5	68.45
15	1995	71.6	8.05	63.55
15	2000	67.35	8.65	58.7
15	2005	63.05	9.35	53.7
15	2010	58.75	10.05	48.7
15	2015	54.55	10.95	43.6
15	2020	50.4	11.8	38.6
15	2025	46.35	12.75	33.6
15	2030	42.45	13.85	28.6
15	2035	38.6	14.95	23.65
15	2040	34.85	16.25	18.6
15	2045	31.1	17.65	13.45
15	2050	27.15	19.15	8
15	2055	24.3	20.8	3.5
15	2060	20.85	22.65	1.8
15	2065	17.95	24.7	6.75
15	2070	15.25	26.9	11.65
15	2075	12.65	29.2	16.55
15	2080	10.2	31.9	21.7
15	2085	8.25	34.8	26.55
15	2090	6.45	37.85	31.4
15	2095	4.95	41.3	36.35
15	2100	3.7	45.2	41.5
15	2105	2.75	49.3	46.55
15	2110	1.975	53.6	51.625

(a) Near term options

tau	K	call_option_p	put_option_p	diff
35	1975	98.55	16.7	81.85
35	1980	94.25	17.45	76.8
35	1985	90.05	18.25	71.8
35	1990	85.9	19.1	66.8
35	1995	81.75	20	61.75
35	2000	77.75	21	56.75
35	2005	73.6	22	51.6
35	2010	69.7	22.95	46.75
35	2015	65.75	24.05	41.7
35	2020	61.85	25.25	36.6
35	2025	58.15	26.45	31.7
35	2030	54.4	27.7	26.7
35	2035	50.85	29.1	21.75
35	2040	47.35	30.55	16.8
35	2045	43.9	32.05	11.85
35	2050	40.5	33.75	6.75
35	2055	37.3	35.45	1.85
35	2060	34.1	37.3	3.2
35	2065	31.15	39.25	8.1
35	2070	28.15	41.4	13.25
35	2075	25.4	43.6	18.2
35	2080	22.75	46	23.25
35	2085	20.3	48.5	28.2
35	2090	18	51.1	33.1
35	2095	15.8	54.05	38.25
35	2100	13.75	56.95	43.2
35	2105	11.85	60.05	48.2
35	2110	10.2	63.4	53.2
35	2115	8.65	66.95	58.3
35	2120	7.35	70.5	63.15
35	2125	6.15	74.3	68.15
35	2130	5.15	78.25	73.1
35	2135	4.25	82.35	78.1
35	2140	3.5	86.65	83.15
35	2145	2.8	91	88.2
35	2150	2.25	95.3	93.05
35	2155	1.925	99.85	97.925

(b) Next term options

Figure 3: Absolute Differences

The chosen options are out-of-the-money SPX calls and puts, centered around an at-the-money strike price, K_0. To calculate the at-the-money strike price we have to find the forward SPX level, F, by identifying the strike price at which the absolute difference between the prices is least (highlighted in red).

Calculating the forward SPX level, F

From the table the difference between the call and put prices is smallest at the 2060 strike for the near-term options and the 1960 strike for next-term. Thus, applying the **2060** call and put near term options, and the **2055** call and put next-term options to the formula to estimate the F:

$$F = \text{Strike Price} + e^{RT} \times (\text{Call Price} - \text{Put Price})$$

NEAR-TERM				
tau	K_0	call_option_price	put_option_price	F
15	2060	20.85	22.65	2058.1999
NEXT-TERM				
tau	K_0	call_option_price	put_option_price	F
35	2055	37.3	35.45	2056.8503

Figure 4: Forward Index Level Calculation

The forward index prices, F_1 and F_2, for the near- and next-term options, respectively, are:

$$F_1 = 2060 + e^{0.0015 \times 0.0410959} \times (20.85 - 22.65) = 2058.1999$$

$$F_2 = 2055 + e^{0.0019 \times 0.0958904} \times (37.3 - 35.45) = 2056.8503$$

```
if row_x[i,'tau']<=30
  then
    do;
    f1[i]= row_x[i,'k'] + exp(row_x[i,'r']*row_x[i, 't1'])*(row_x[i,'c'] - row_x[i,'p']);
    k01[i] = max(options[loc(date = (date1[i]) & options[,'tau'] =  (row_x[i,'tau']) &
  options[,'k'] < (f1[i])), 'k']);
        end;
  else
    do;
    f2[i]= row_x[i,'k'] + exp(row_x[i,'r']*row_x[i, 't2'])*(row_x[i,'c'] - row_x[i,'p']);
    k02[i] = max(options[loc(date = (date1[i]) & options[,'tau'] =  (row_x[i,'tau']) &
  options[,'k'] < (f2[i])), 'k']);
        end;
```

K_0 refers to the strike price just below the forward index level, F, for both the near-term and next-term options. In this example, $K_{0,1} = 2055$ and $K_{0,2} = 2055$.

Calculating the Mid-quote prices

- If the strike is above K_0 we used the call price as the $Q(K_i)$.
- If the strike is below K_0 we used the put price as the $Q(K_i)$.
- If the strike equals K_0 we used the average of the call and put prices as the $Q(K_i)$.

```
  if matrix2[j, 'k'] < coalesce(k01[i], k02[i])
  then do;
    mid_qoute_price[j] = matrix2[j,'p'];
    option_type[j] = 'PUT';
    end;
  else if matrix2[j, 'k'] > coalesce(k01[i], k02[i])
  then do;
    mid_qoute_price[j] = matrix2[j,'c'];
    option_type[j] = 'CALL';
    end;
  else if matrix2[j, 'k'] = coalesce(k01[i], k02[i])
  then do;
    mid_qoute_price[j] =(matrix2[j,'p'] + matrix2[j,'c'])/2;
    option_type[j] = 'PUT/CALL AVG.';
      end;
```

K	option_type	mid_qoute_price
1965	PUT	5.15
1970	PUT	5.55
1975	PUT	6
1980	PUT	6.45
1985	PUT	6.9
1990	PUT	7.5
1995	PUT	8.05
2000	PUT	8.65
2005	PUT	9.35
2010	PUT	10.05
2015	PUT	10.95
2020	PUT	11.8
2025	PUT	12.75
2030	PUT	13.85
2035	PUT	14.95
2040	PUT	16.25
2045	PUT	17.65
2050	PUT	19.15
2055	**PUT/CALL AVG.**	**22.55**
2060	CALL	20.85
2065	CALL	17.95
2070	CALL	15.25
2075	CALL	12.65
2080	CALL	10.2
2085	CALL	8.25
2090	CALL	6.45
2095	CALL	4.95
2100	CALL	3.7
2105	CALL	2.75
2110	CALL	1.975

(a) Near term options

K	option_type	mid_qoute_price
1975	PUT	16.7
1980	PUT	17.45
1985	PUT	18.25
1990	PUT	19.1
1995	PUT	20
2000	PUT	21
2005	PUT	22
2010	PUT	22.95
2015	PUT	24.05
2020	PUT	25.25
2025	PUT	26.45
2030	PUT	27.7
2035	PUT	29.1
2040	PUT	30.55
2045	PUT	32.05
2050	PUT	33.75
2055	**PUT/CALL AVG.**	**36.375**
2060	CALL	34.1
2065	CALL	31.15
2070	CALL	28.15
2075	CALL	25.4
2080	CALL	22.75
2085	CALL	20.3
2090	CALL	18
2095	CALL	15.8
2100	CALL	13.75
2105	CALL	11.85
2110	CALL	10.2
2115	CALL	8.65
2120	CALL	7.35
2125	CALL	6.15
2130	CALL	5.15
2135	CALL	4.25
2140	CALL	3.5
2145	CALL	2.8
2150	CALL	2.25
2155	CALL	1.925

(b) Next term options

Figure 5: MID-QUOTE PRICES

STEP 2: Computing strike price contributions

The contribution of the option is given by:

$$\frac{\Delta K_i}{K_i^2} e^{RT} Q(K_i)$$

Calculating ΔK_i

ΔK_i represents half the disparity between the strike prices surrounding ΔK_i. At the boundaries of any options strip, ΔK_i is straightforwardly the gap between K_i and the adjacent strike price. i.e.
ΔK_i is half the difference between the strike prices on either side of K_i:

$$\Delta K_i = \frac{1}{2}(K_{i+1} - K_{i-1})$$

At the upper and lower edges of any given strip of options, ΔK_i is simply the difference between K_i and the adjacent strike price:

$\Delta K_{\text{upper}} = K_i - K_{i-1}$
$\Delta K_{\text{lower}} = K_{i+1} - K_i$

```
cnt = cnt + 1;
  if cnt = 1
  then
     delta[j] = (matrix2[j+1, 'k'] - matrix2[j, 'k']); /*lower edge*/

  else if j=nrow(matrix2) | matrix2[min(j+1, nrow(matrix2)), 'tau'] ^= matrix2[j, 'tau'] |
    date_f[min(j+1, nrow(matrix2))] ^= date_f[j]
  then
    delta[j]= (matrix2[j, 'k'] - matrix2[j-1, 'k']);/*upper edge*/
  else
    delta[j] = (matrix2[j+1, 'k'] - matrix2[j-1, 'k'])/2;
```

Calculating contribution for each strike price

The contribution of near-term 1965 can be computed by :

$$\frac{\Delta K_{1965\text{Put}}}{K^2_{1965\text{Put}}} e^{R_1 T_1} Q(K_{1965\text{Put}})$$

$$\frac{\Delta K_{1965\text{Put}}}{K^2_{1965\text{Pu}}} e^{R_1 T_1} Q(K_{1965\text{Put}}) = \frac{5}{1965^2} e^{0.0015*0.0410959} * 20$$

Similarly the contribution is calculated for each strike prices of near and next terms.

The resulting values for the near-term options and next-term options are summed and multiplied by $2/T_1$ and $2/T_2$ respectively.

$$\frac{2}{T} \sum_i \frac{\Delta K_i}{K_i^2} e^{RT} Q(K_i)$$

for neat-term= 1.87E-02
for neat-term= 1.74E-02

K	option_type	mid_qoute_price	contributions_by_strike
1965	PUT	5.15	6.67E-06
1970	PUT	5.55	7.15E-06
1975	PUT	6	7.69E-06
1980	PUT	6.45	8.23E-06
1985	PUT	6.9	8.76E-06
1990	PUT	7.5	9.47E-06
1995	PUT	8.05	0.0000101
2000	PUT	8.65	0.0000108
2005	PUT	9.35	0.0000116
2010	PUT	10.05	0.0000124
2015	PUT	10.95	0.0000135
2020	PUT	11.8	0.0000145
2025	PUT	12.75	0.0000155
2030	PUT	13.85	0.0000168
2035	PUT	14.95	0.0000181
2040	PUT	16.25	0.0000195
2045	PUT	17.65	0.0000211
2050	PUT	19.15	0.0000228
2055	**PUT/CALL AVG.**	**22.55**	**0.0000267**
2060	CALL	20.85	0.0000246
2065	CALL	17.95	0.000021
2070	CALL	15.25	0.0000178
2075	CALL	12.65	0.0000147
2080	CALL	10.2	0.0000118
2085	CALL	8.25	9.49E-06
2090	CALL	6.45	7.38E-06
2095	CALL	4.95	5.64E-06
2100	CALL	3.7	4.20E-06
2105	CALL	2.75	3.10E-06
2110	CALL	1.975	2.22E-06

(a) Near term options

K	option_type	mid_qoute_price	contributions_by_strike
1975	PUT	16.7	0.0000214
1980	PUT	17.45	0.0000223
1985	PUT	18.25	0.0000232
1990	PUT	19.1	0.0000241
1995	PUT	20	0.0000251
2000	PUT	21	0.0000263
2005	PUT	22	0.0000274
2010	PUT	22.95	0.0000284
2015	PUT	24.05	0.0000296
2020	PUT	25.25	0.0000309
2025	PUT	26.45	0.0000323
2030	PUT	27.7	0.0000336
2035	PUT	29.1	0.0000351
2040	PUT	30.55	0.0000367
2045	PUT	32.05	0.0000383
2050	PUT	33.75	0.0000402
2055	**PUT/CALL AVG.**	**36.375**	**0.0000431**
2060	CALL	34.1	0.0000402
2065	CALL	31.15	0.0000365
2070	CALL	28.15	0.0000329
2075	CALL	25.4	0.0000295
2080	CALL	22.75	0.0000263
2085	CALL	20.3	0.0000234
2090	CALL	18	0.0000206
2095	CALL	15.8	0.000018
2100	CALL	13.75	0.0000156
2105	CALL	11.85	0.0000134
2110	CALL	10.2	0.0000115
2115	CALL	8.65	9.67E-06
2120	CALL	7.35	8.18E-06
2125	CALL	6.15	6.81E-06
2130	CALL	5.15	5.68E-06
2135	CALL	4.25	4.66E-06
2140	CALL	3.5	3.82E-06
2145	CALL	2.8	3.04E-06
2150	CALL	2.25	2.43E-06
2155	CALL	1.925	2.07E-06

(b) Next term options

Figure 6: CONTRIBUTIONS

STEP 3: Calculating Volatility

Near-Term Options

$$\sigma_1^2 = \frac{2}{T_1}\sum_i \frac{\Delta K_i}{K_i^2} e^{R_1 T_1} Q(K_i) - \frac{1}{T_1}\left(\frac{F_1}{K_0} - 1\right)^2$$

Next-Term Options

$$\sigma_2^2 = \frac{2}{T_2}\sum_i \frac{\Delta K_i}{K_i^2} e^{R_2 T_2} Q(K_i) - \frac{1}{T_2}\left(\frac{F_2}{K_0} - 1\right)^2$$

```
total_contribution_near = j(nrow(row_x), 1, .);
total_contribution_next = j(nrow(row_x), 1, .);
volatility1  = j(nrow(row_x), 1, .);
volatility2  = j(nrow(row_x), 1, .);
do i = 1 to nrow(row_x);
  if row_x[i,'tau']<=30
  then do;
    total_contribution_near[i] = sum(contributions_by_strike[loc(date_f = date1[i] & matrix2
  [, 'tau'] = row_x[i, 'tau'] )]);
    volatility1[i] = (2/row_x[i, 't1'])*total_contribution_near[i];
    volatility1[i] = volatility1[i] - (1/row_x[i, 't1'])*(f1[i]/k01[i]-1)##2;
    end;
  else do;
    total_contribution_next[i] = sum(contributions_by_strike[loc(date_f = date1[i] & matrix2
  [, 'tau'] = row_x[i, 'tau'] )]);
    volatility2[i] = (2/row_x[i, 't2'])*total_contribution_next[i];
    volatility2[i] = volatility2[i] - (1/row_x[i, 't2'])*(f2[i]/k02[i]-1)##2;
    end;
end;
```

NEAR-TERM VOLATILITY	NEXT-TERM VOLATILITY
0.0185972	0.0173467

Figure 7: Volatility

STEP 3: Calculating the 30-day weighted average variance

30-day weighted average variance:

$$\left\{T_1\sigma_1^2\left[\frac{N_{T_2} - N_{30}}{N_{T_2} - N_{T_1}}\right] + T_2\sigma_2^2\left[\frac{N_{30} - N_{T_1}}{N_{T_2} - N_{T_1}}\right]\right\} \times \frac{N_{365}}{N_{30}}$$

where,

NT1 = number of minutes to settlement of the near-term options (35,924)

NT2 = number of minutes to settlement of the next-term options (46,394)

N30 = number of minutes in 30 days (30 x 1,440 = 43,200)

N365 = number of minutes in a 365-day year (365 x 1,440 = 525,600)

As we have used the τ value instead to calculating the expiration time in minutes we can equate then following values for the N Variables:
NT1 = τ_1
NT2 = τ_2
N30 = 30
N365 = 365

To obtain the VIX value we have to take the square root of the 30-day weighted average variance and multiply it by 100

$$\text{VIX} = 100 \times \sqrt{\left\{T_1\sigma_1^2\left[\frac{N_{T_2}-N_{30}}{N_{T_2}-N_{T_1}}\right]+T_2\sigma_2^2\left[\frac{N_{30}-N_{T_1}}{N_{T_2}-N_{T_1}}\right]\right\}\times\frac{N_{365}}{N_{30}}}$$

On substituting:

$$\text{VIX} = 100 \times \sqrt{\left\{0.0410959 \times 0.0185972\left[\frac{37-30}{37-15}\right]+0.0958904 \times 0.0173467\left[\frac{30-15}{37-15}\right]\right\}\times\frac{365}{30}}$$

$$VIX = 100 \times 0.1323 = 13.23$$

We have generalized the SAS code to compute the VIX for other dates. This is done by removing the code to filter the data for 2nd of Jan. The VIX values obtained over the two months have been plotted against the dates in the graph below:

```
proc sgplot data=vix_data;
  series x=date1 y=VIX / markers markerattrs=(symbol=circlefilled);
  xaxis label="Date";
  yaxis label="VIX";
  title "VIX";
run;
```

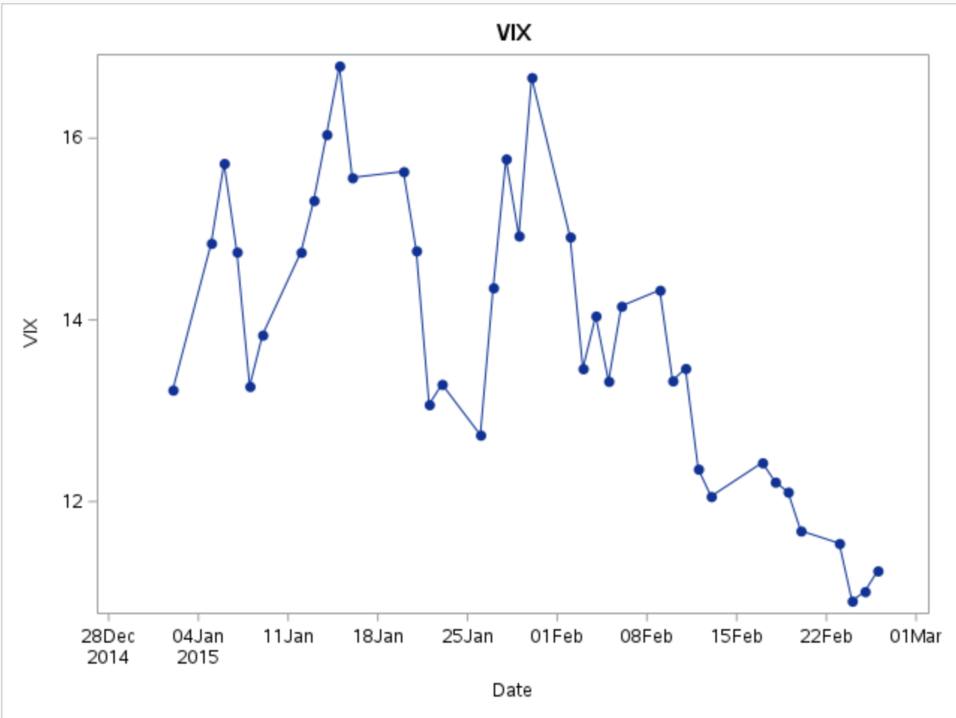

Figure 8: VIX vs Date