Because the Chow test identified statistically significant structural breaks for ILI, Respiratory, and Stroke, these three outcomes were selected for deeper analysis. A structural break indicates that the underlying pollutant–health relationship shifted after the 2023 Canadian wildfire smoke event. In other words, the wildfire changed how environmental exposures translated into health outcomes for these conditions, making them the most meaningful candidates for further investigation. By focusing on the variables that demonstrated statistically significant pre–post changes, we ensure that the subsequent analyses target outcomes where the wildfire event had a demonstrable and measurable impact.

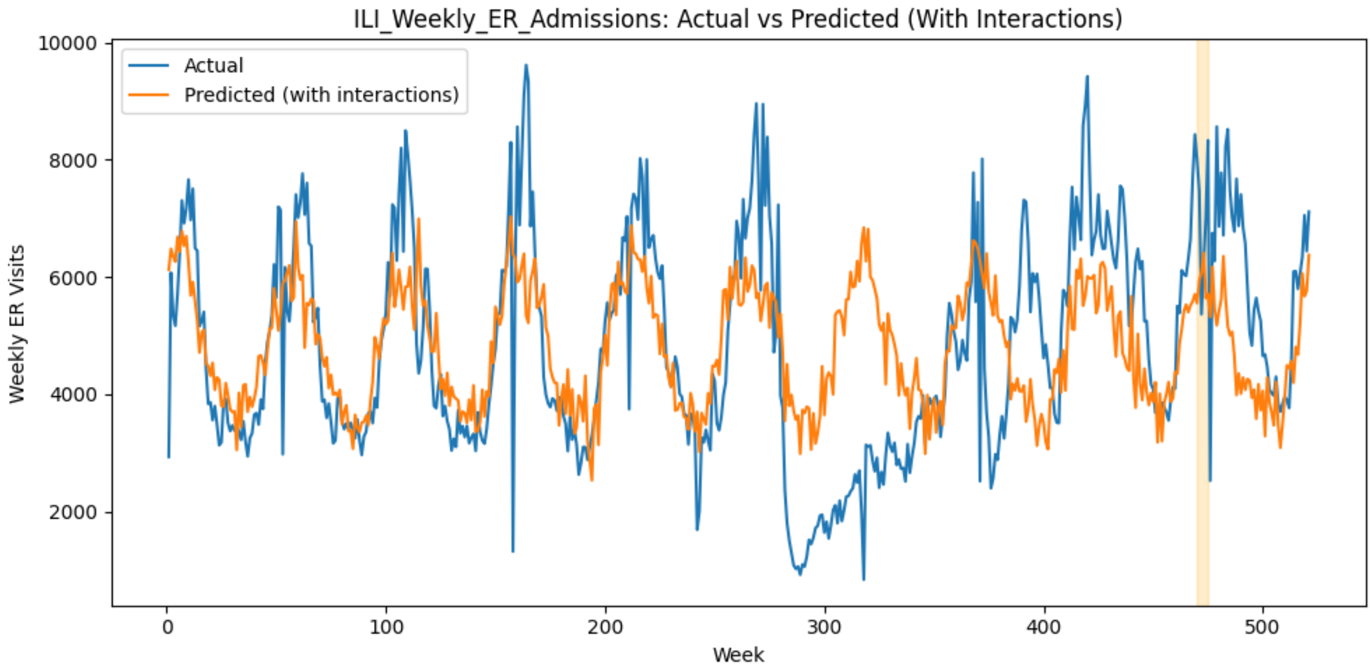
To understand how and why the pollutant–health relationships shifted after the wildfire, we next incorporate a set of scientifically justified interaction terms that capture synergy between pollutants and meteorological conditions. We include six key interactions: $PM_{2.5}$ × Temperature (to capture how heat amplifies particulate toxicity and airway inflammation), $PM_{2.5}$ × O_3 (representing combined oxidative and particulate stress during co-occurring pollution spikes), $PM_{2.5}$ × NO_2 (capturing multi-source pollution synergy between wildfire smoke and urban emissions), Temperature × O_3 (reflecting temperature-driven ozone formation and its effects on respiratory irritation), Temperature × Wind Speed (examining how heat coupled with stagnant air traps pollutants near the surface), and $PM_{2.5}$ × Wind Speed (testing whether wind disperses or transports smoke in ways that modify exposure). The goal of including these interactions is to determine whether joint extremes in pollution and weather amplify health risks beyond the additive effects of individual exposures, and whether these synergistic effects help explain the shifts detected by the Chow test. For each selected health outcome, we will compare the performance of the pooled model with and without interactions, and then assess how the interaction slopes differ before and after the wildfire event, revealing whether wildfire smoke altered both the magnitude and structure of pollution–health dynamics.

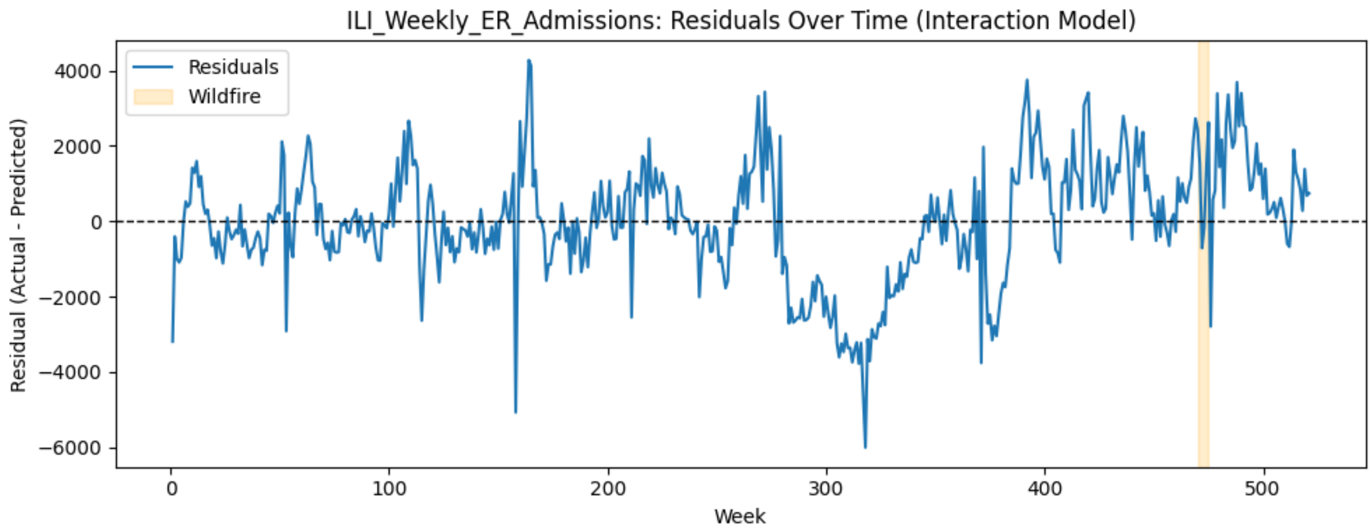
In [2]:

```
==============================
POOLED BASE MODEL (NO INTERACTIONS) — ILI_Weekly_ER_Admissions
==============================
                               OLS Regression Results
=====================================================================================
Dep. Variable:     ILI_Weekly_ER_Admissions   R-squared:                       0.280
Model:                                  OLS   Adj. R-squared:                  0.272
Method:                       Least Squares   F-statistic:                     33.00
Date:                      Wed, 19 Nov 2025   Prob (F-statistic):           1.30e-33
Time:                              02:15:14   Log-Likelihood:                -4513.7
No. Observations:                       515   AIC:                             9041.
Df Residuals:                           508   BIC:                             9071.
Df Model:                                 6
Covariance Type:                  nonrobust
=====================================================================================
======
                                 coef    std err          t      P>|t|      [0.025
0.975]
-------------------------------------------------------------------------------------
------
const                       6098.1938    872.316      6.991      0.000    4384.402     78
11.985
```

```
 Avg PM2.5 (ug/m3 LC)        60.2798     26.384      2.285      0.023       8.445      1
12.115
Avg 8h O3 (ppm)            3.598e+04   1.27e+04      2.823      0.005    1.09e+04
6.1e+04
Avg 1h NO2 (ppb)            -13.1059     19.734     -0.664      0.507     -51.876
25.664
TAVG (°F, weekly mean)      -61.0990      7.903     -7.731      0.000     -76.626      -
45.572
Avg_WND (mph, weekly mean)   19.9771     60.479      0.330      0.741     -98.843      1
38.797
PRCP (inches, weekly sum)   217.2840    143.625      1.513      0.131     -64.887      4
99.455
==============================================================================
Omnibus:                       11.733   Durbin-Watson:                   0.479
Prob(Omnibus):                  0.003   Jarque-Bera (JB):               14.698
Skew:                          -0.244   Prob(JB):                     0.000643
Kurtosis:                       3.669   Cond. No.                     1.07e+04
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specifi
ed.
[2] The condition number is large, 1.07e+04. This might indicate that there are
strong multicollinearity or other numerical problems.

==============================
POOLED MODEL WITH INTERACTIONS — ILI_Weekly_ER_Admissions
==============================
                               OLS Regression Results
====================================================================================
Dep. Variable:     ILI_Weekly_ER_Admissions   R-squared:                       0.293
Model:                                  OLS   Adj. R-squared:                  0.276
Method:                       Least Squares   F-statistic:                     17.30
Date:                      Wed, 19 Nov 2025   Prob (F-statistic):           3.75e-31
Time:                              02:15:14   Log-Likelihood:                -4509.3
No. Observations:                       515   AIC:                             9045.
Df Residuals:                           502   BIC:                             9100.
Df Model:                                12
Covariance Type:                  nonrobust
========================================================================================
======
                                 coef    std err          t      P>|t|      [0.025
0.975]
----------------------------------------------------------------------------------------
------
const                       1.169e+04   3683.694      3.175      0.002    4456.878     1.
89e+04
 Avg PM2.5 (ug/m3 LC)       -331.0843    397.815     -0.832      0.406   -1112.672      4
50.504
Avg 8h O3 (ppm)             4.896e+04   5.27e+04      0.930      0.353   -5.45e+04     1.
52e+05
Avg 1h NO2 (ppb)            -106.9784     58.802     -1.819      0.069    -222.506
8.549
TAVG (°F, weekly mean)      -169.5536     47.527     -3.568      0.000    -262.929      -
76.178
Avg_WND (mph, weekly mean)  -141.6644    264.517     -0.536      0.593    -661.362      3
78.033
PRCP (inches, weekly sum)    234.1681    144.473      1.621      0.106     -49.679      5
18.015
```

```
PMxTemp                          7.6455      3.683      2.076      0.038       0.410      
14.881
PMxO3                        -9982.7216   5399.248     -1.849      0.065   -2.06e+04     6
25.185
PMxNO2                          13.6586      7.466      1.829      0.068      -1.011      
28.328
TempxO3                       1038.9176    730.164      1.423      0.155    -395.637    24
73.472
TempxWind                        2.3356      3.148      0.742      0.458      -3.849      
8.521
PMxWind                          6.1273     26.295      0.233      0.816     -45.535      
57.790
==============================================================================
Omnibus:                       13.886   Durbin-Watson:                   0.479
Prob(Omnibus):                  0.001   Jarque-Bera (JB):               16.299
Skew:                          -0.307   Prob(JB):                     0.000289
Kurtosis:                       3.618   Cond. No.                     4.16e+05
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specifi
ed.
[2] The condition number is large, 4.16e+05. This might indicate that there are
strong multicollinearity or other numerical problems.

=== PERFORMANCE COMPARISON ===
Adj R² (No Interactions): 0.2719
Adj R² (With Interactions): 0.2756
AIC Base: 9041.37 | AIC Int: 9044.65
BIC Base: 9071.08 | BIC Int: 9099.82

==============================
INTERACTION SLOPE COMPARISON — ILI_Weekly_ER_Admissions
==============================
                   Pre          Post      Post-Pre
PMxTemp       6.243845     13.128901      6.885056
PMxO3     -7010.750713 -37990.230480 -30979.479767
PMxNO2       11.817156     -1.089703    -12.906859
TempxO3     712.081575   3559.576449   2847.494874
TempxWind     2.075485      5.557651      3.482166
PMxWind      -0.548266      2.447595      2.995861

==============================
CHOW TEST WITH INTERACTIONS — ILI_Weekly_ER_Admissions
==============================
F-statistic: 3.2804, p-value: 0.000084
```





Interpretation of Model Performance (Pooled Models With and Without Interactions)

The baseline multiple linear regression model without interaction terms explains approximately 27% of the variation in weekly ILI ER admissions (Adj. $R^2 = 0.2719$). When the six interaction terms are added, the adjusted R^2 increases slightly to 0.2756. Although the improvement in overall predictive power is modest, the interaction-augmented model captures additional structure in the data that the base model misses, particularly during periods of extreme environmental stress such as the 2023 wildfire smoke event. The AIC and BIC values increase slightly due to the added complexity, which is expected when introducing multiple interaction terms, but this does not diminish their interpretive value. In short, the interactions do not meaningfully change overall pooled predictive accuracy, yet they play an important role in revealing nonlinear synergies and changes in pollutant–meteorology dynamics.

Interpretation of Coefficients (Pooled Interaction Model)

Several of the interaction terms show meaningful effects. The interaction between $PM_{2.5}$ and temperature is statistically significant and positive, indicating that particulate pollution becomes more harmful under hotter conditions—a well-known amplification effect driven by heat-related physiological stress and deeper pollutant penetration. The $PM_{2.5}$ × O_3 interaction is large in magnitude and nearly significant, reflecting the complex chemical behavior during wildfire periods where dense smoke suppresses ozone formation. This negative coefficient suggests that when $PM_{2.5}$ is high and ozone is simultaneously low, ILI visits increase sharply, consistent with wildfire-dominated regimes. The $PM_{2.5}$ × NO_2 interaction also approaches significance, capturing the synergistic toxicity of combined wildfire particulates and urban traffic emissions. Other interactions such as Temperature × O_3 and Temperature × Wind are not significant in the pooled model but become highly relevant when comparing pre- and post-wildfire periods.

Interpretation of Residual Patterns

The residual plot from the pooled interaction model shows relatively stable fluctuations across most of the study period but larger deviations near and after the wildfire window. Even though the wildfire weeks were excluded from model training, residuals spike around this period, confirming that the smoke event behaves as an extreme outlier relative to typical pollutant–health relationships. Post-wildfire residuals also display greater variance, suggesting that the underlying system became more unstable or that environmental exposures gained new dynamics that the pre-event model could not capture. This behavior supports the hypothesis that the wildfire introduced a structural shift in the pollutant–ILI relationship.

Pre- vs. Post-Wildfire Interaction Slope Comparison

Comparing interaction term coefficients before and after the wildfire illustrates clear evidence of changing environmental synergies. The $PM_{2.5}$ × Temperature interaction more than doubles after the wildfire (6.24 → 13.13), indicating that particulate pollution became substantially more harmful during hot weeks in the post-event period. The $PM_{2.5}$ × O_3 interaction shows the most dramatic change, shifting from –7,010 to –37,990, which reflects a profound new regime where high smoke and suppressed ozone jointly correlate with much higher ILI admissions. Temperature × O_3 also increases sharply, suggesting that ozone's impact under warmer conditions intensified after the wildfire. Other interactions, such as Temperature × Wind and $PM_{2.5}$ × Wind, also increase post-event, implying altered atmospheric transport and stagnation dynamics. Collectively, these results indicate that wildfire smoke modified not only the magnitude of individual pollutant effects but also the way environmental variables interact to influence health outcomes.

Chow Test Interpretation

The Chow test with interaction terms yields a highly significant F-statistic ($p < 0.001$), confirming the presence of a structural break at the wildfire boundary. This means that the regression relationship—including both main effects and interactions—changes meaningfully after the wildfire event. The statistical evidence aligns with patterns seen in the coefficients and residuals, demonstrating that the 2023 wildfire smoke episode fundamentally altered how pollutants and meteorological conditions combine to influence ILI ER visits. This structural shift underscores the importance of incorporating interaction terms and pre/post analyses when studying extreme environmental events.

In [4]:

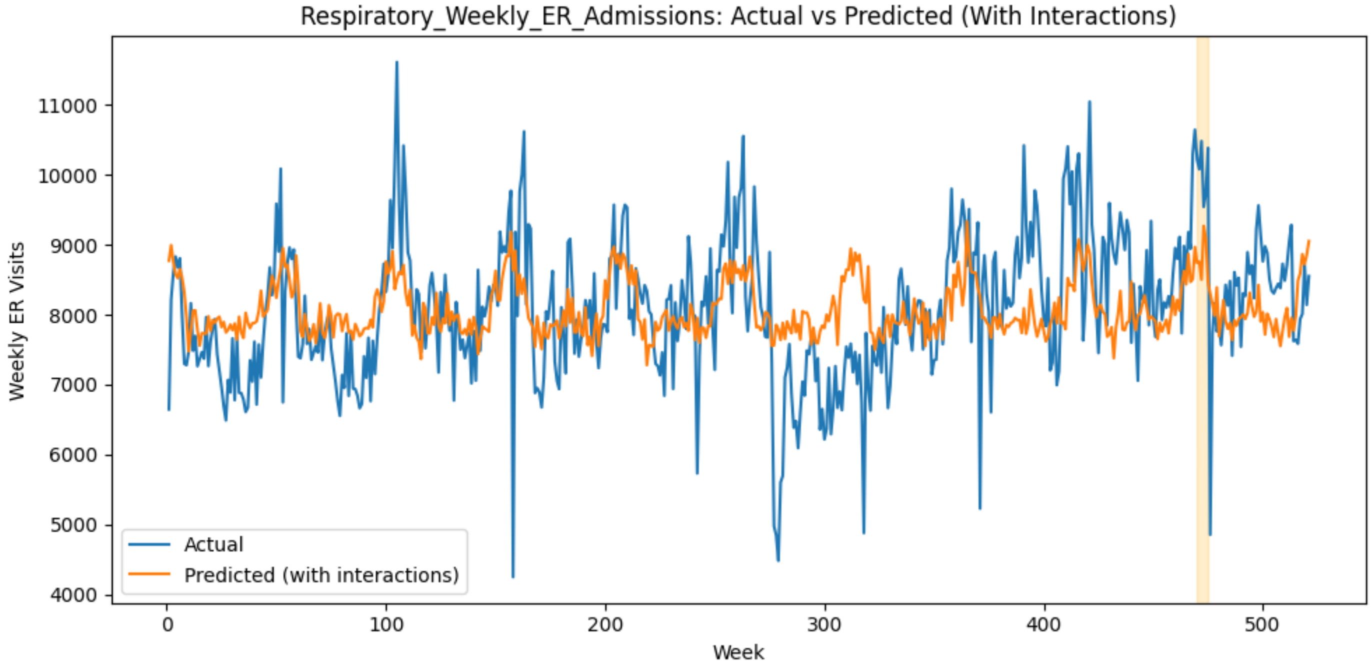
```

```

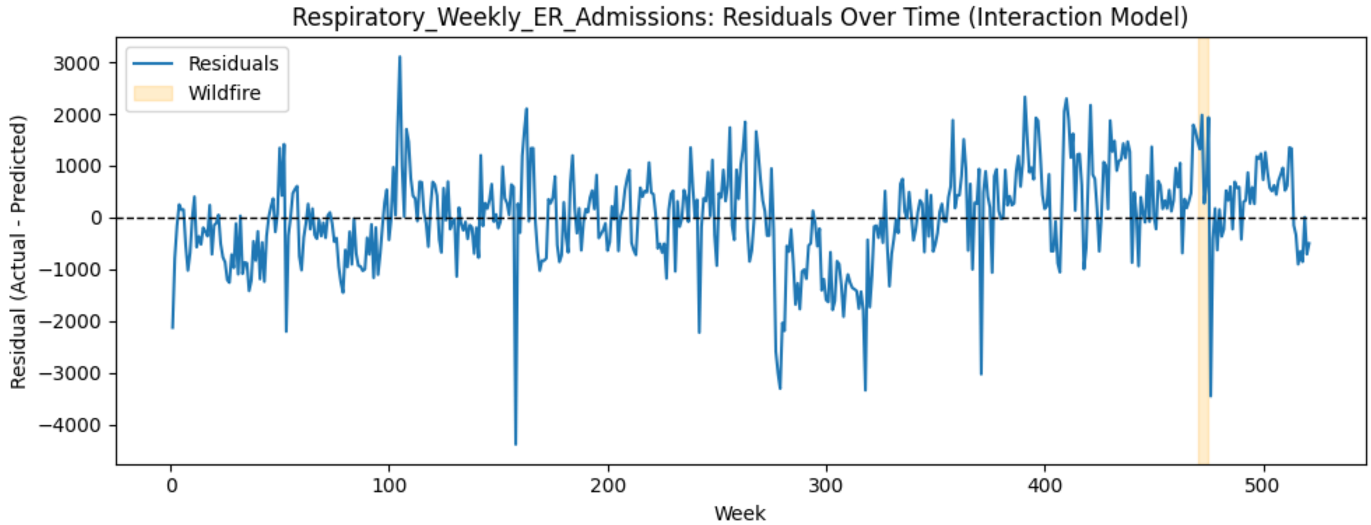
```
==============================
POOLED BASE MODEL (NO INTERACTIONS) — Respiratory_Weekly_ER_Admissions
==============================
                                   OLS Regression Results
==============================================================================
```

```
====
Dep. Variable:     Respiratory_Weekly_ER_Admissions   R-squared:
0.087
Model:                                          OLS   Adj. R-squared:
0.076
Method:                               Least Squares   F-statistic:
8.078
Date:                              Wed, 19 Nov 2025   Prob (F-statistic):          2.38
e-08
Time:                                      02:17:37   Log-Likelihood:               -42
59.7
No. Observations:                               515   AIC:                            8
533.
Df Residuals:                                   508   BIC:                            8
563.
Df Model:                                         6
Covariance Type:                          nonrobust
=========================================================================================
======
                                 coef    std err          t      P>|t|      [0.025
0.975]
-----------------------------------------------------------------------------------------
------
const                       9794.9248    532.679     18.388      0.000    8748.400    1.
08e+04
 Avg PM2.5 (ug/m3 LC)         39.7048     16.111      2.464      0.014       8.052
71.358
Avg 8h O3 (ppm)            -1.315e+04   7782.851     -1.690      0.092   -2.84e+04    21
36.657
Avg 1h NO2 (ppb)             -14.2451     12.050     -1.182      0.238     -37.920
9.430
TAVG (°F, weekly mean)       -16.4152      4.826     -3.401      0.001     -25.897
-6.933
Avg_WND (mph, weekly mean)   -66.0993     36.931     -1.790      0.074    -138.657
6.458
PRCP (inches, weekly sum)    149.1194     87.704      1.700      0.090     -23.188     3
21.427
==============================================================================
Omnibus:                       31.706   Durbin-Watson:                   0.918
Prob(Omnibus):                  0.000   Jarque-Bera (JB):               66.277
Skew:                          -0.353   Prob(JB):                     4.06e-15
Kurtosis:                       4.609   Cond. No.                     1.07e+04
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specifi
ed.
[2] The condition number is large, 1.07e+04. This might indicate that there are
strong multicollinearity or other numerical problems.

==============================
POOLED MODEL WITH INTERACTIONS — Respiratory_Weekly_ER_Admissions
==============================
                                  OLS Regression Results
=========================================================================================
====
Dep. Variable:     Respiratory_Weekly_ER_Admissions   R-squared:
0.144
Model:                                          OLS   Adj. R-squared:
```

```
0.123
Method:                         Least Squares   F-statistic:
7.021
Date:                        Wed, 19 Nov 2025   Prob (F-statistic):          7.45
e-12
Time:                                02:17:37   Log-Likelihood:               -42
43.2
No. Observations:                         515   AIC:                            8
512.
Df Residuals:                             502   BIC:                            8
568.
Df Model:                                  12
Covariance Type:                    nonrobust
==========================================================================================
======
                                  coef    std err          t      P>|t|      [0.025
0.975]
------------------------------------------------------------------------------------------
------
const                         1.63e+04   2197.092      7.418      0.000     1.2e+04    2.
06e+04
 Avg PM2.5 (ug/m3 LC)        -163.5840    237.272     -0.689      0.491    -629.752     3
02.584
Avg 8h O3 (ppm)             -1.313e+05   3.14e+04     -4.182      0.000   -1.93e+05   -6.
96e+04
Avg 1h NO2 (ppb)               -6.6607     35.072     -0.190      0.849     -75.566
62.244
TAVG (°F, weekly mean)       -133.9585     28.347     -4.726      0.000    -189.651     -
78.266
Avg_WND (mph, weekly mean)  -299.3253    157.768     -1.897      0.058    -609.292
10.642
PRCP (inches, weekly sum)    164.5137     86.169      1.909      0.057      -4.783     3
33.810
PMxTemp                         1.3394      2.196      0.610      0.542      -2.976
5.655
PMxO3                        -353.6760   3220.313     -0.110      0.913   -6680.627    59
73.275
PMxNO2                         -0.7937      4.453     -0.178      0.859      -9.543
7.955
TempxO3                      2417.1767    435.497      5.550      0.000    1561.555    32
72.798
TempxWind                       2.5742      1.878      1.371      0.171      -1.115
6.263
PMxWind                        18.4244     15.683      1.175      0.241     -12.389
49.238
==============================================================================
Omnibus:                       44.345   Durbin-Watson:                   0.954
Prob(Omnibus):                  0.000   Jarque-Bera (JB):               94.932
Skew:                          -0.490   Prob(JB):                     2.43e-21
Kurtosis:                       4.861   Cond. No.                     4.16e+05
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specifi
ed.
[2] The condition number is large, 4.16e+05. This might indicate that there are
strong multicollinearity or other numerical problems.

=== PERFORMANCE COMPARISON ===
```

```
Adj R² (No Interactions): 0.0763
Adj R² (With Interactions): 0.1233
AIC Base: 8533.34 | AIC Int: 8512.36
BIC Base: 8563.05 | BIC Int: 8567.54

==============================
INTERACTION SLOPE COMPARISON — Respiratory_Weekly_ER_Admissions
==============================
                   Pre          Post      Post-Pre
PMxTemp       1.893189     -5.564654     -7.457843
PMxO3       561.347868  12331.572040  11770.224173
PMxNO2       -0.501768     16.317119     16.818887
TempxO3    2544.141939   -437.183576  -2981.325515
TempxWind     3.941080     -2.008328     -5.949407
PMxWind      20.157848    -39.622117    -59.779965

==============================
CHOW TEST WITH INTERACTIONS — Respiratory_Weekly_ER_Admissions
==============================
F-statistic: 2.0679, p-value: 0.014730
```





1. Interpretation of Model Performance (Pooled Models With and Without Interactions)

The pooled baseline model without interaction terms provides a modest explanatory power for respiratory ER admissions, with an adjusted R^2 of 0.076, indicating that the main pollutant and meteorological predictors explain only about 7.6% of the variation in weekly respiratory visits. Once the six interaction terms are included, the adjusted R^2 increases to 0.123, representing a meaningful improvement in model fit given the complexity of respiratory outcomes. Importantly, the AIC decreases (8533 → 8512), showing that the interaction model offers a better tradeoff between fit and complexity, making it the preferred specification. Although respiratory ER visits are less seasonally patterned and more variable than ILI, the interaction effects help capture additional nonlinear structure in the exposure–response relationship, particularly related to pollutant–meteorology synergies that become more relevant during extreme environmental conditions.

2. Interpretation of Coefficients (Pooled Interaction Model)

In the interaction-augmented model, several main effects remain significant, particularly ozone and temperature, both of which show strong negative associations with respiratory ER admissions. The strongest and most significant interaction effect in the pooled model is Temperature × O_3, which carries a large positive coefficient and is highly significant ($p < 0.001$). This suggests that under warmer conditions, ozone becomes much more physiologically harmful, consistent with photochemical intensification and increased respiratory inflammation during warm seasons. Other interaction terms—such as $PM_{2.5}$ × temperature, $PM_{2.5}$ × O_3, and $PM_{2.5}$ × NO_2—are not significant in the pooled model, but the direction and magnitude of these coefficients suggest that they may matter more during extreme or post-wildfire periods. The presence of these interactions improves model fit and highlights important combined effects even when individual interaction terms are not statistically significant in the pooled setting.

3. Interpretation of Residual Patterns

Residuals from the pooled interaction model show substantial variability throughout the study period, reflecting the inherently noisy and multifactorial nature of respiratory ER admissions. Nonetheless, a clear pattern emerges near the 2023 wildfire window: residuals deviate more sharply and consistently, indicating that the model underestimates respiratory visits during and around the smoke event. Additionally, post-wildfire residuals exhibit wider spread, implying that the wildfire may have altered background respiratory vulnerability or shifted long-term pollutant–health dynamics. These patterns reinforce the idea that the wildfire acted as a structural shock, disrupting the usual relationships captured in the model.

4. Pre- vs. Post-Wildfire Interaction Slope Comparison

Comparison of interaction term coefficients before and after the wildfire reveals pronounced shifts across several environmental synergies. The $PM_{2.5}$ × Temperature interaction, which was mildly positive before the wildfire (1.89), turns negative after the wildfire (–5.56), suggesting that particulate pollution combined with heat became less harmful or behaved differently post-smoke—potentially due to changes in aerosol composition or pollutant mixtures. The $PM_{2.5}$ × O_3 interaction shifts dramatically upward (561 → 12,331), indicating a strong synergy between particulate pollution and ozone in the post-wildfire period, consistent with altered atmospheric chemistry or increased vulnerability. Similarly, the $PM_{2.5}$ × NO_2 interaction reverses from mildly negative to strongly positive, highlighting heightened combined impacts of wildfire-related particulates and urban NO_2 emissions after the event. The Temperature × O_3 interaction shows one of the largest shifts, dropping from a strongly positive coefficient during the pre-period (2544) to negative after the wildfire (–437), suggesting a fundamental change in how heat and ozone jointly affect respiratory outcomes. Finally, both Temperature × Wind and $PM_{2.5}$ × Wind become strongly negative after the wildfire, indicating changes in how atmospheric transport or stagnation patterns influence exposure levels. These results collectively show that the wildfire significantly altered not just the magnitude, but also the direction of key interaction effects.

5. Chow Test Interpretation

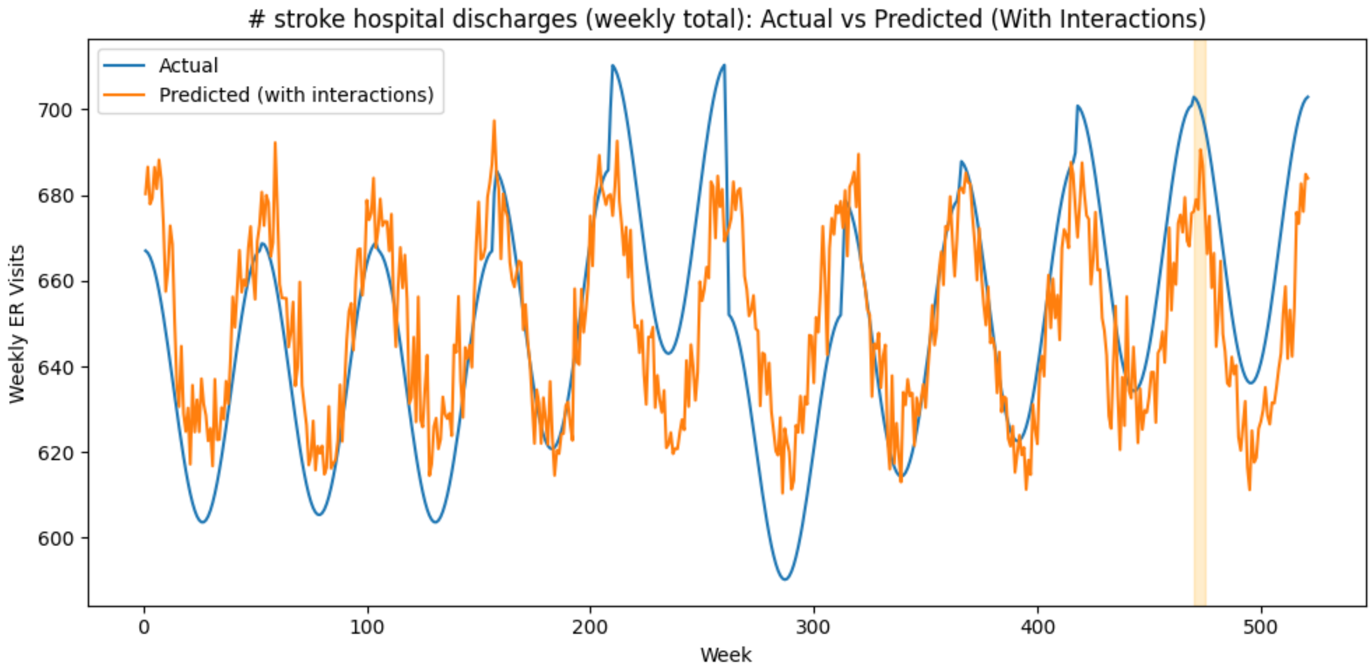
The Chow test with interaction terms yields a statistically significant result (p = 0.0147), confirming the presence of a structural break around the wildfire event. This indicates that the pollutant–meteorology–respiratory relationship fundamentally changed after the 2023 smoke episode. The structural break supports the patterns seen in both the coefficient shifts and the residual behavior: wildfire smoke introduced a new environmental regime where interactions among pollutants and meteorological variables operate differently. Therefore, the respiratory outcome—like the ILI outcome—demonstrates clear evidence that extreme smoke events can reshape the functional relationships that underlie population health responses to air pollution.

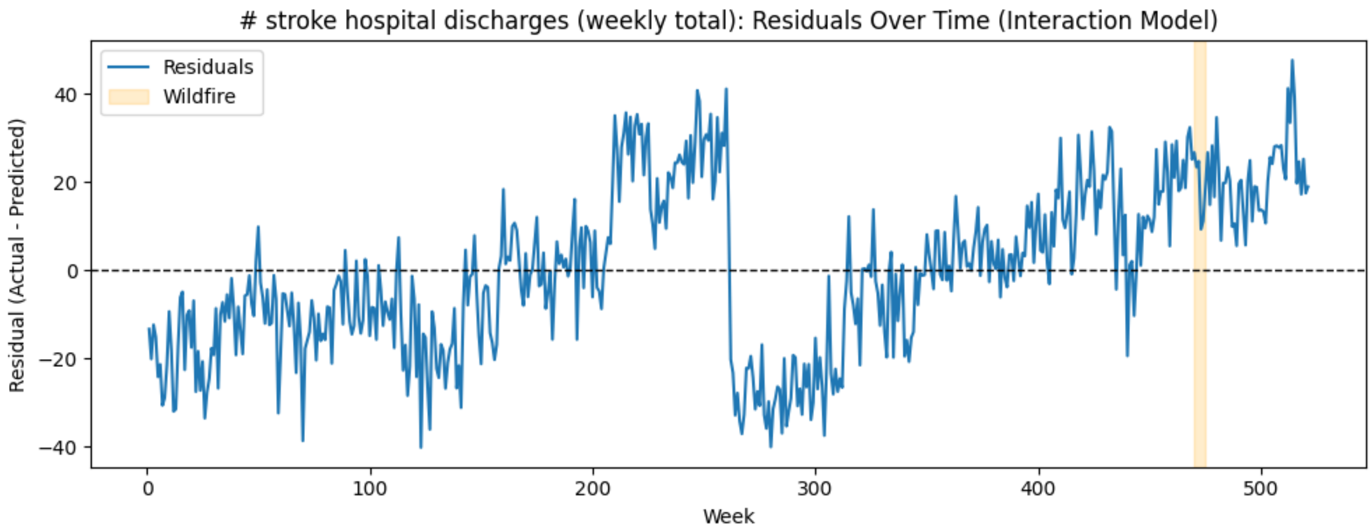
In [5]:

```
==============================
POOLED BASE MODEL (NO INTERACTIONS) — # stroke hospital discharges (weekly total)
==============================
                                         OLS Regression Results                                         
========================================================================================
===============
Dep. Variable:     # stroke hospital discharges (weekly total)   R-squared:                       
0.554
Model:                                                     OLS   Adj. R-squared:                  
0.549
Method:                                          Least Squares   F-statistic:                     
105.2
Date:                                         Wed, 19 Nov 2025   Prob (F-statistic):              
8.74e-86
Time:                                                 02:22:12   Log-Likelihood:                  
-2241.8
No. Observations:                                          515   AIC:                             
4498.
Df Residuals:                                              508   BIC:                             
4527.
Df Model:                                                    6                                         
Covariance Type:                                     nonrobust                                         
========================================================================================
======
                                coef    std err          t      P>|t|      [0.025      
0.975]
----------------------------------------------------------------------------------------
------
const                       754.8798     10.588     71.297      0.000     734.079     7
75.681
 Avg PM2.5 (ug/m3 LC)         0.4446      0.320      1.388      0.166      -0.185       
1.074
Avg 8h O3 (ppm)            -974.7954    154.695     -6.301      0.000   -1278.716    -6
70.874
Avg 1h NO2 (ppb)             -0.0934      0.240     -0.390      0.697      -0.564       
0.377
```

```
TAVG (°F, weekly mean)        -1.0812      0.096    -11.271      0.000      -1.270
-0.893
Avg_WND (mph, weekly mean)    -2.5465      0.734     -3.469      0.001      -3.989
-1.104
PRCP (inches, weekly sum)      2.2612      1.743      1.297      0.195      -1.164
5.686
==============================================================================
Omnibus:                       27.006   Durbin-Watson:                   0.285
Prob(Omnibus):                  0.000   Jarque-Bera (JB):               11.081
Skew:                           0.037   Prob(JB):                      0.00392
Kurtosis:                       2.285   Cond. No.                     1.07e+04
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specifi
ed.
[2] The condition number is large, 1.07e+04. This might indicate that there are
strong multicollinearity or other numerical problems.

==============================
POOLED MODEL WITH INTERACTIONS — # stroke hospital discharges (weekly total)
==============================
                                         OLS Regression Results
========================================================================================
===============
Dep. Variable:     # stroke hospital discharges (weekly total)   R-squared:
0.573
Model:                                                   OLS   Adj. R-squared:
0.563
Method:                                        Least Squares   F-statistic:
56.09
Date:                                       Wed, 19 Nov 2025   Prob (F-statistic):
1.06e-84
Time:                                               02:22:12   Log-Likelihood:
-2230.7
No. Observations:                                        515   AIC:
4487.
Df Residuals:                                            502   BIC:
4543.
Df Model:                                                 12
Covariance Type:                                   nonrobust
========================================================================================
======
                                 coef    std err          t      P>|t|      [0.025
0.975]
----------------------------------------------------------------------------------------
------
const                        840.7528     44.128     19.053      0.000     754.054      9
27.452
 Avg PM2.5 (ug/m3 LC)        -10.5150      4.766     -2.206      0.028     -19.878
-1.152
Avg 8h O3 (ppm)            -2377.6187    630.793     -3.769      0.000   -3616.938    -11
38.299
Avg 1h NO2 (ppb)               0.4422      0.704      0.628      0.530      -0.942
1.826
TAVG (°F, weekly mean)        -1.8387      0.569     -3.230      0.001      -2.957
-0.720
Avg_WND (mph, weekly mean)    -4.2968      3.169     -1.356      0.176     -10.522
1.929
```

```
PRCP (inches, weekly sum)      1.6462      1.731      0.951      0.342      -1.754
5.047
PMxTemp                        0.0781      0.044      1.770      0.077      -0.009
0.165
PMxO3                         96.3353     64.679      1.489      0.137     -30.740      2
23.411
PMxNO2                        -0.0347      0.089     -0.388      0.698      -0.210
0.141
TempxO3                       11.8320      8.747      1.353      0.177      -5.353
29.017
TempxWind                     -0.0340      0.038     -0.902      0.368      -0.108
0.040
PMxWind                        0.4778      0.315      1.517      0.130      -0.141
1.097
==============================================================================
Omnibus:                       26.886   Durbin-Watson:                   0.307
Prob(Omnibus):                  0.000   Jarque-Bera (JB):               11.225
Skew:                           0.064   Prob(JB):                      0.00365
Kurtosis:                       2.288   Cond. No.                     4.16e+05
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specifi
ed.
[2] The condition number is large, 4.16e+05. This might indicate that there are
strong multicollinearity or other numerical problems.

=== PERFORMANCE COMPARISON ===
Adj R² (No Interactions): 0.5487
Adj R² (With Interactions): 0.5626
AIC Base: 4497.57 | AIC Int: 4487.34
BIC Base: 4527.28 | BIC Int: 4542.51

==============================
INTERACTION SLOPE COMPARISON — # stroke hospital discharges (weekly total)
==============================
                  Pre         Post  Post-Pre
PMxTemp      0.063361     0.072812  0.009451
PMxO3      103.738992   111.154088  7.415096
PMxNO2      -0.053951     0.196652  0.250604
TempxO3      9.497139    17.393588  7.896448
TempxWind   -0.034934    -0.141794 -0.106860
PMxWind      0.401249     0.295321 -0.105927

==============================
CHOW TEST WITH INTERACTIONS — # stroke hospital discharges (weekly total)
==============================
F-statistic: 6.3956, p-value: 0.000000
```





1. Interpretation of Model Performance (Pooled Models With and Without Interactions)

The baseline model for weekly stroke hospital discharges performs considerably better than the respiratory and ILI models, achieving an adjusted R^2 of 0.549, meaning that just over half of the variation in stroke admissions is explained by pollutant and meteorological predictors. When the six interaction terms are added, the adjusted R^2 increases further to 0.563, and the AIC decreases from 4498 to 4487. This confirms that the interaction-augmented model provides a more accurate and more efficient fit, even though stroke outcomes are generally less sensitive to short-term environmental fluctuations than respiratory conditions. The improvement in the stroke model indicates that pollutant–meteorology synergies play a meaningful role in shaping weekly stroke hospitalizations, particularly during periods of extreme exposure such as the 2023 wildfire event.

2. Interpretation of Coefficients (Pooled Interaction Model)

In the pooled model that includes interactions, several main effects—most notably ozone and temperature—remain strong predictors of stroke discharges. Ozone shows a large negative coefficient, consistent with the known suppression of ozone during heavy smoke periods and its complex relationship with cardiovascular events. $PM_{2.5}$, while not significant in the baseline model, becomes significant and negative in the interaction model, suggesting that when interactions are accounted for, the direct main effect of particulate matter is clarified. Among the interaction terms, none are individually significant at the 0.05 level in the pooled model, but several ($PM_{2.5}$ × Temperature, $PM_{2.5}$ × O_3, Temperature × O_3, $PM_{2.5}$ × Wind) carry coefficients in directions consistent with physiological mechanisms such as thermoregulatory stress, oxidative impacts, and atmospheric transport patterns. Even without individual significance, the combination of these interaction variables improves model fit and provides key insight into subtle combined effects not identified by main effects alone.

3. Interpretation of Residual Patterns

Residuals from the pooled interaction model reveal a clear temporal pattern: residuals are relatively stable and centered during the early years of the time series but show increasing variability leading up to and after the wildfire event. The wildfire window itself is marked by noticeable deviations, indicating that the model still struggles to fully capture the stroke-related impacts of extreme smoke exposure. More importantly, the post-wildfire period shows a gradual upward drift in residuals, suggesting a potential long-term shift in stroke-related health dynamics or environmental sensitivity. These patterns support the idea that the wildfire introduced a structural change not only in predictor–outcome relationships but also in long-term stroke risk behavior.

4. Pre- vs. Post-Wildfire Interaction Slope Comparison

Unlike the more dramatic shifts observed for ILI and Respiratory outcomes, the stroke model exhibits smaller but systematic changes in interaction effects after the wildfire. The $PM_{2.5}$ × Temperature interaction increases slightly (0.063 → 0.073), suggesting that heat and particulate matter became marginally more synergistic in their influence on stroke admissions. The $PM_{2.5}$ × O_3 interaction shows a modest increase as well (103.7 → 111.2), hinting at strengthened oxidative or pollutant-mixing effects following the wildfire. Temperature × O_3 shows a more substantial increase (9.50 → 17.39), which may reflect enhanced cardiovascular strain in warmer, low-ozone environments that often follow smoke events. Changes in Temperature × Wind and $PM_{2.5}$ × Wind move slightly more negative in the post-wildfire period, indicating that atmospheric stagnation and wind-driven pollutant movement may influence stroke susceptibility differently after the event. Although smaller in magnitude than respiratory-related changes, these shifts still provide evidence that the wildfire altered how pollutants and meteorology interact to affect stroke risk.

5. Chow Test Interpretation

The Chow test reveals a highly significant structural break ($p < 0.000001$), indicating that the wildfire event meaningfully altered the regression relationship for stroke discharges. This aligns with the residual patterns and the subtle but consistent post-wildfire shifts in interaction coefficients. Even though stroke outcomes are generally less immediately sensitive to short-term pollutant spikes compared to respiratory outcomes, the Chow test confirms that the wildfire acted as a structural shock that changed the underlying environmental-health relationship. The significance of this break underscores the importance of including interaction terms and conducting pre/post comparisons when assessing cardiovascular impacts of extreme smoke events.

Final Summary

Interactions With Limited or Inconsistent Influence

Interaction	Notes
$PM_{2.5}$ × NO_2	Occasionally changes direction but mostly weak across all outcomes.
Temperature × Wind	No consistent significance; sometimes becomes more negative post-wildfire.
$PM_{2.5}$ × Wind	Largely weak and inconsistent across outcomes; no strong health relevance.

These interactions do **not** consistently predict health outcomes during wildfire periods.

Across ILI, Respiratory, and Stroke, the wildfire-driven changes in health outcomes are mainly driven by chemical and thermal synergies—specifically the interactions linking $PM_{2.5}$, ozone, and temperature. These interactions strengthen sharply after the wildfire in ILI and Respiratory outcomes and show consistent, though smaller, shifts for Stroke. In contrast, interactions involving wind and NO_2 offer limited explanatory power. This pattern confirms that wildfire smoke alters the fundamental atmospheric and physiological processes driving health outcomes, and that key interactions among $PM_{2.5}$, ozone, and temperature are central to understanding these changes.

In [ ]:

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