U.S. Storm Event Predictability

By Denise Macias

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Purpose

The purpose of this project will be to determine the predictability of recent storm events in the U.S. through historical data.

Data

- Source: National Climatic Data Center

- Original dataset:
  - 1,740,597 observations
  - 51 features
  - 70 event types
  - 1950-2022

- Cleaned dataset:
  - 1,740,597 observations
  - 17 features
  - 70 event types
  - 1950-2022

Data Exploration

- **Target:** Magnitude
- **Focus:** Identify storm events that hold the most promise for a reliable magnitude forecast using the following criteria:
    - 1) Events for which magnitude is tracked
    - 2) Events with the highest event counts
    - 3) Events with the highest casualties

Data Exploration: Events Identified

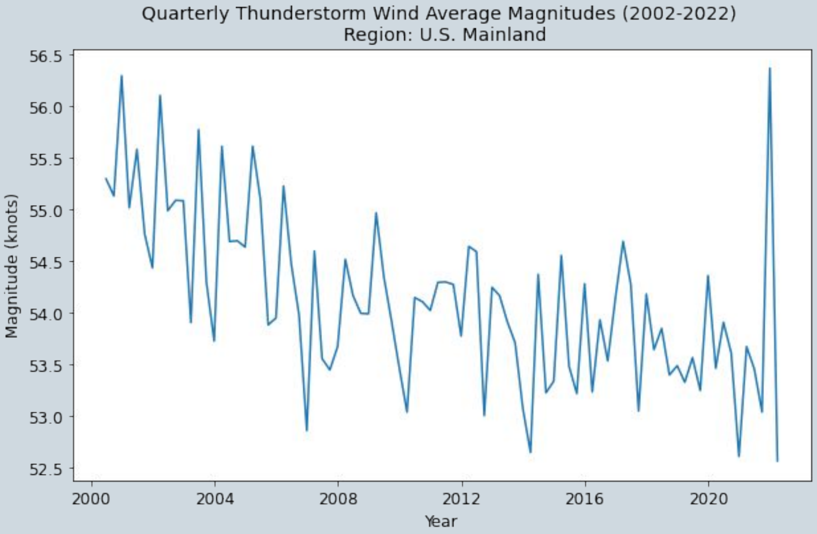
- **Thunderstorm Wind**
  - 484,908 events
  - 11,609 injuries; 2,048 deaths; 15 billion in damages
- **Tornado**
  - 73,987 events
  - 97,472 injuries; 12,230 deaths; 7 billion in damages
- **Hail**
  - 382,234 events
  - 1,563 injuries; 30 deaths; 34 billion in damages
- **High Wind**
  - 79,894 events
  - 1,986 injuries; 706 deaths; 16 billion in damages

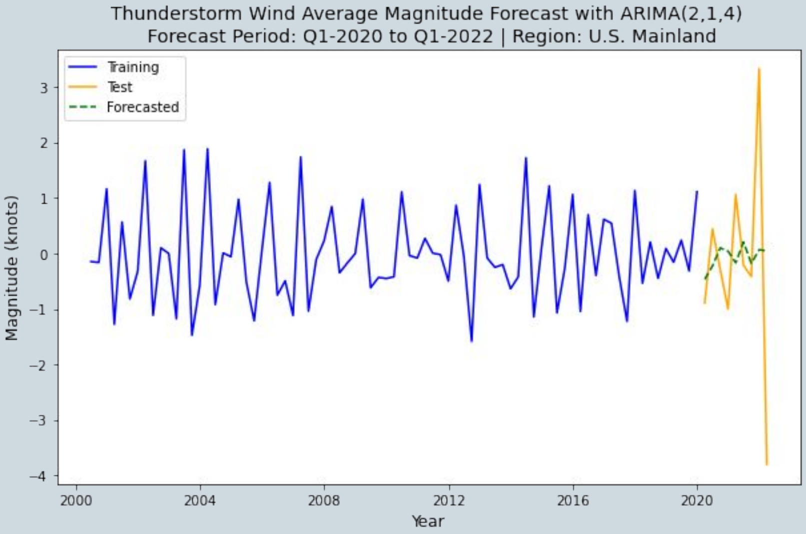
Data Exploration: Event Findings

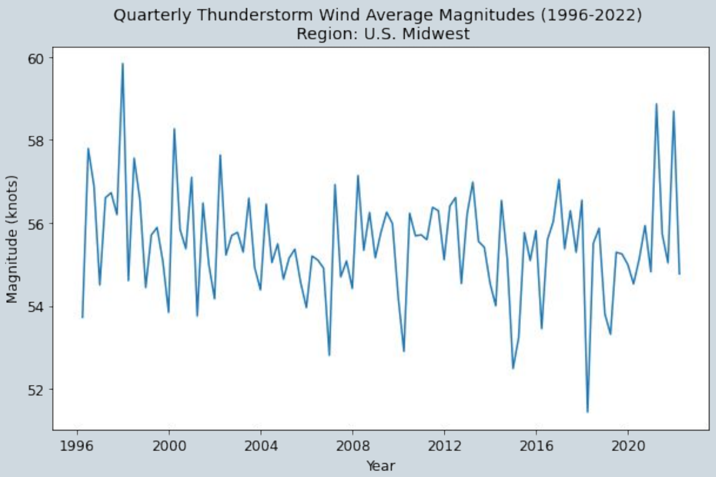
- **Thunderstorm Wind (1955-2022) → Contender**
  - Very chaotic from 1955-1996 and not representative of recent data
  - Better consistency from 1996-2022
  - Regions vary greatly from the national trend
    - % of data per region: South (48%), Midwest (36%), Northeast (11%), West (5%)
    - Midwest and West experience most severe thunderstorm wind events
- **Tornado (1950-2022) → Disqualified**
  - No records after 2006
- **Hail (1955-2022) → Contender**
  - A little chaotic from 1955-2000 and not representative of recent data
  - Better consistency from 2000-2022
  - Regions do not vary as much from national trend
    - % of data per region: Midwest (44%), South (42%), West (9%), Northeast (4%)
    - Midwest and South experience most severe hail events
- **High Wind (1996-2022) → Disqualified**
  - Chaotic all throughout and no consistency

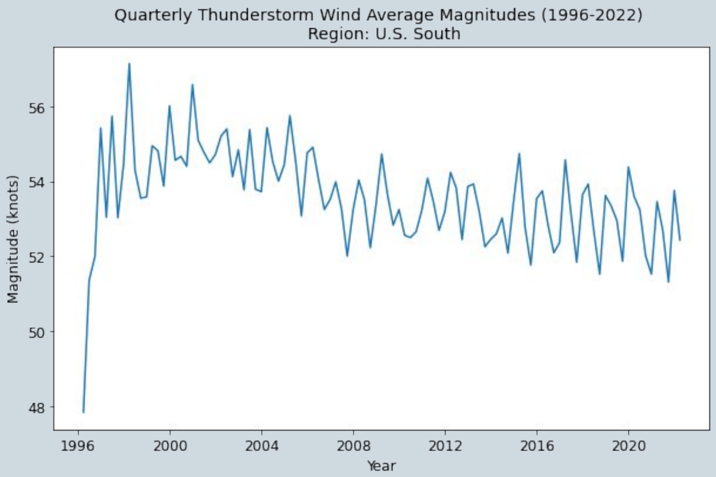
Thunderstorm Wind

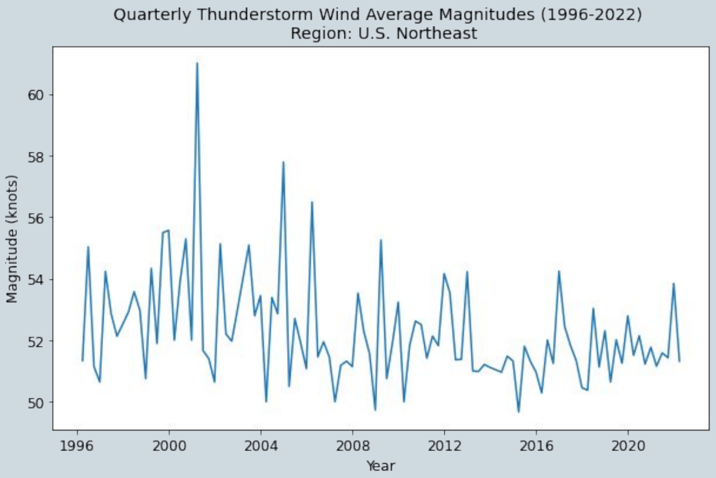
ARIMA Model Forecasts

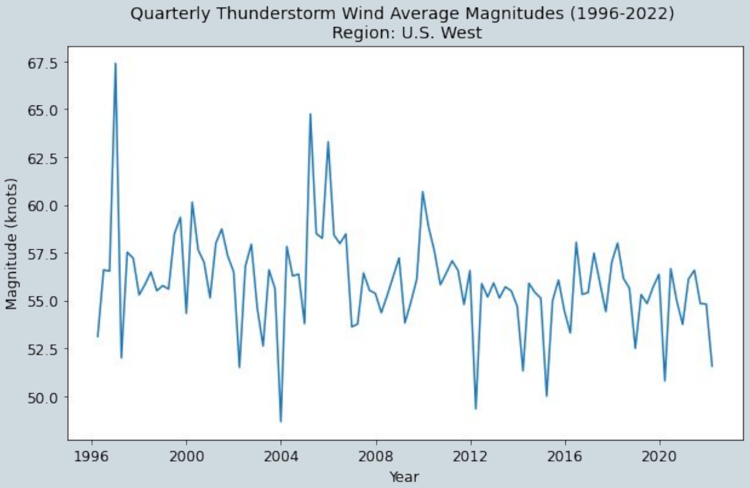


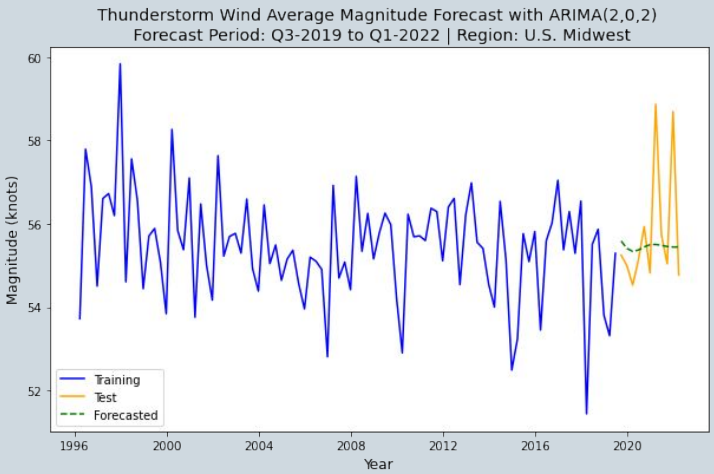


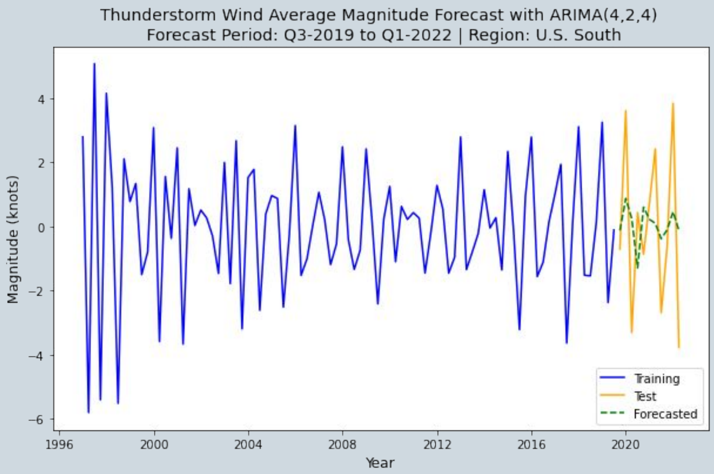

Quarterly Thunderstorm Wind Average Magnitudes (1996-2022)
Region: U.S. Midwest
Magnitude (knots)
Year
60
58
56
54
52
1996
2000
2004
2008
2012
2016
2020

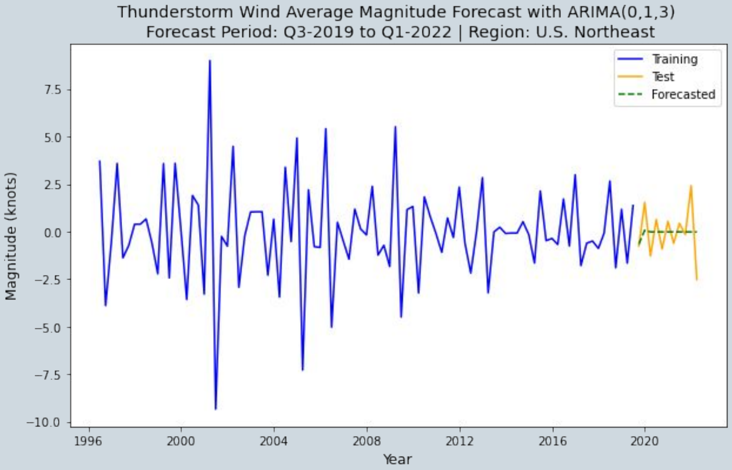

Quarterly Thunderstorm Wind Average Magnitudes (1996-2022)
Region: U.S. South
Magnitude (knots)
Year
56
54
52
50
48
1996
2000
2004
2008
2012
2016
2020

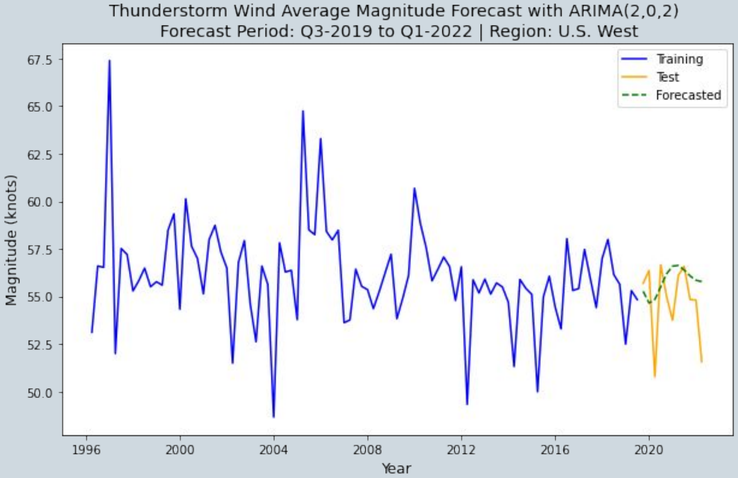

Quarterly Thunderstorm Wind Average Magnitudes (1996-2022)
Region: U.S. Northeast
Magnitude (knots)
Year
60
58
56
54
52
50
1996
2000
2004
2008
2012
2016
2020


Quarterly Thunderstorm Wind Average Magnitudes (1996-2022)
Region: U.S. West
Magnitude (knots)
Year
67.5
65.0
62.5
60.0
57.5
55.0
52.5
50.0
1996
2000
2004
2008
2012
2016
2020


Thunderstorm Wind Average Magnitude Forecast with ARIMA(2,0,2)
Forecast Period: Q3-2019 to Q1-2022 | Region: U.S. Midwest
Magnitude (knots)
Year
Training
Test
Forecasted


Thunderstorm Wind Average Magnitude Forecast with ARIMA(4,2,4)
Forecast Period: Q3-2019 to Q1-2022 | Region: U.S. South
Magnitude (knots)
Year
Training
Test
Forecasted


Thunderstorm Wind Average Magnitude Forecast with ARIMA(0,1,3)
Forecast Period: Q3-2019 to Q1-2022 | Region: U.S. Northeast
Magnitude (knots)
Year
Training
Test
Forecasted

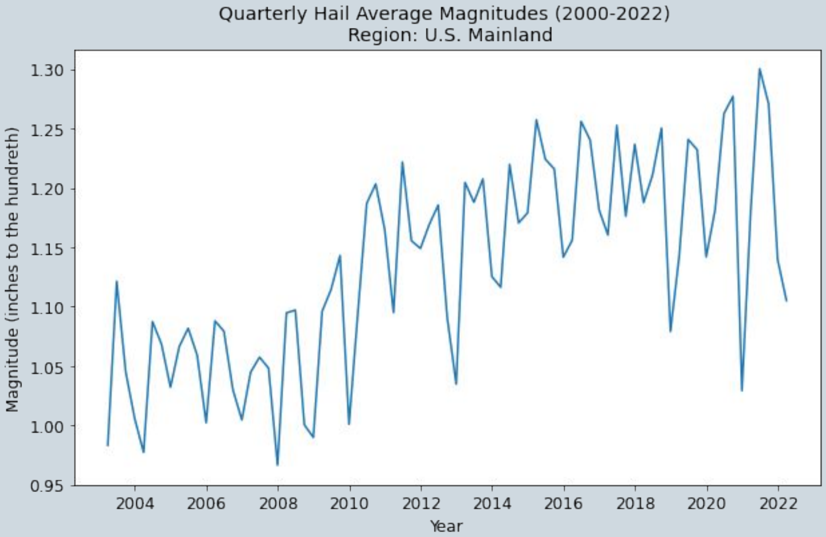

Thunderstorm Wind Average Magnitude Forecast with ARIMA(2,0,2)
Forecast Period: Q3-2019 to Q1-2022 | Region: U.S. West
Magnitude (knots)
Year
Training
Test
Forecasted

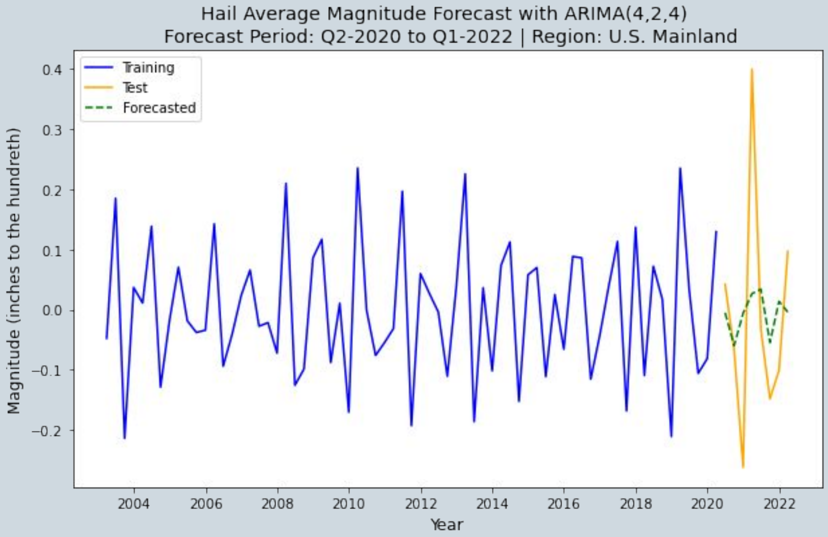
ARIMA Model Findings

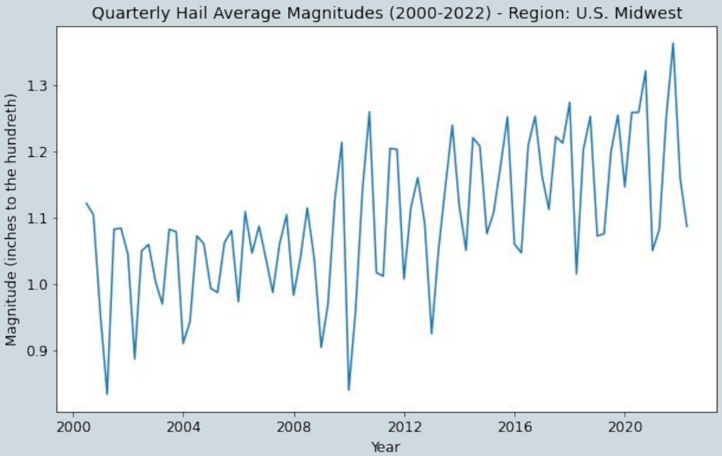
- **U.S. Mainland**
  - The ARIMA (2,1,4) model explained -2% of the variability
  - Did not produce a reliable forecast → RMSE (1.80) > STD (0.98)
- **Midwest**
  - The ARIMA (2,0,2) model explained -4% of the variability
  - Did not produce a reliable forecast → RMSE (1.49) > STD (1.32)
- **South**
  - The ARIMA (4,2,4) model explained 10% of the variability
  - Did not produce a reliable forecast → RMSE (2.37) > STD (2.12)
- **Northeast**
  - The ARIMA (0,1,3) model explained 4% of the variability
  - Produced a reliable forecast→ RMSE (1.28) < STD (1.52)
- **West**
  - The ARIMA (2,0,2) model explained -30% of the variability
  - Produced a reliable forecast → RMSE (2.16) < STD (2.66)

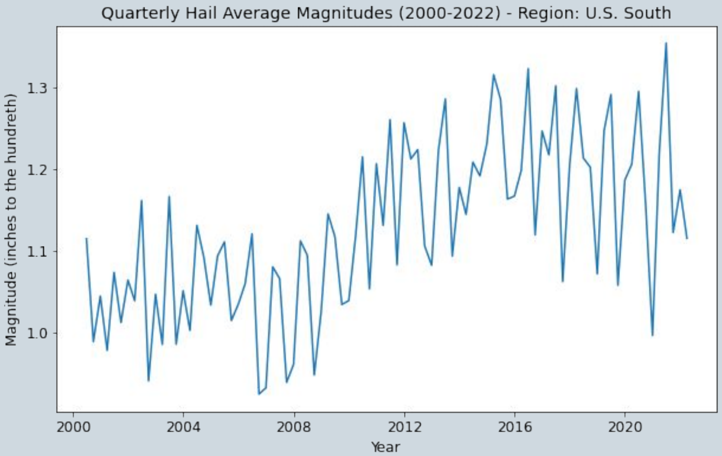
Hail

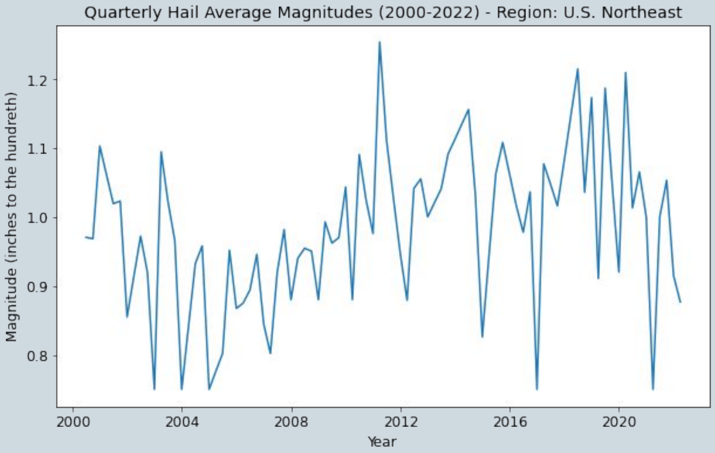
ARIMA Model Forecasts

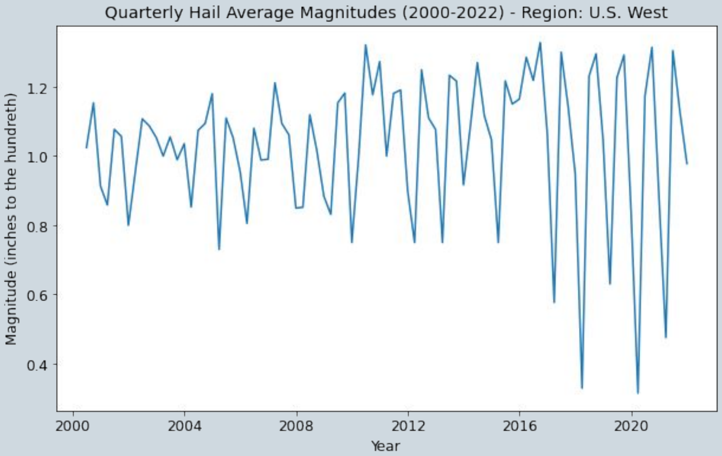


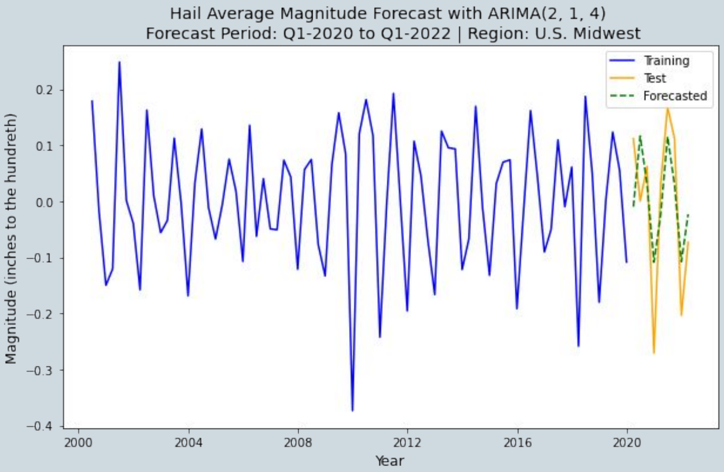


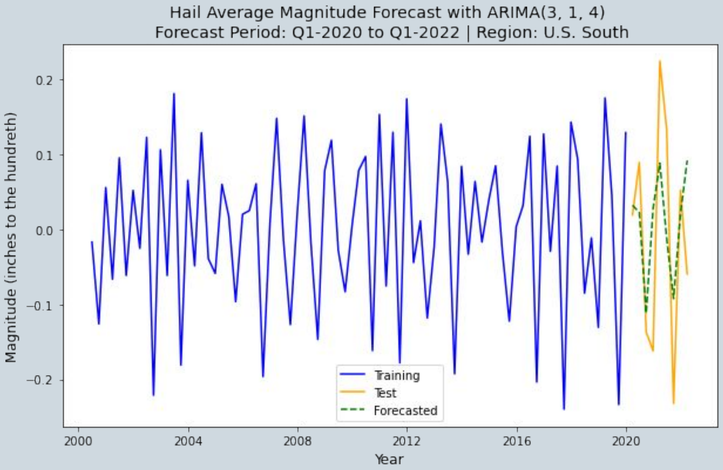

Quarterly Hail Average Magnitudes (2000-2022) - Region: U.S. Midwest
Magnitude (inches to the hundreth)
1.3
1.2
1.1
1.0
0.9
2000
2004
2008
2012
2016
2020
Year

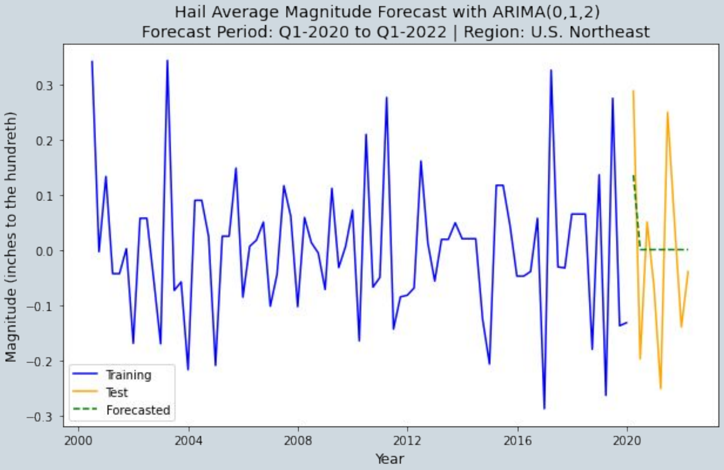

Quarterly Hail Average Magnitudes (2000-2022) - Region: U.S. South
Magnitude (inches to the hundreth)
1.3
1.2
1.1
1.0
2000
2004
2008
2012
2016
2020
Year

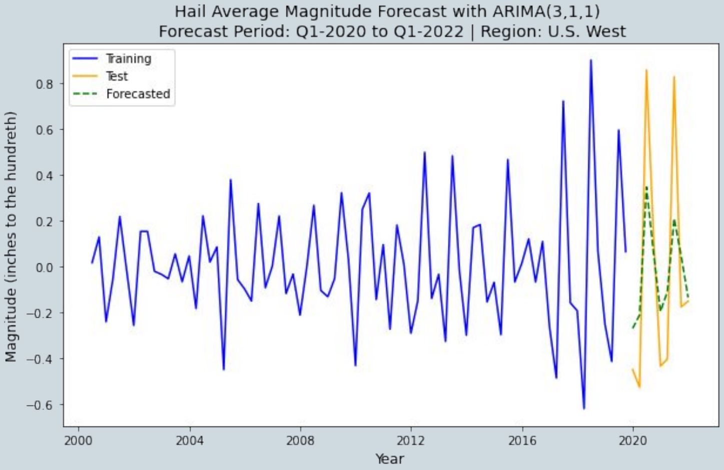

Quarterly Hail Average Magnitudes (2000-2022) - Region: U.S. Northeast
Magnitude (inches to the hundreth)
1.2
1.1
1.0
0.9
0.8
2000
2004
2008
2012
2016
2020
Year


Quarterly Hail Average Magnitudes (2000-2022) - Region: U.S. West
Magnitude (inches to the hundreth)
1.2
1.0
0.8
0.6
0.4
2000
2004
2008
2012
2016
2020
Year


Hail Average Magnitude Forecast with ARIMA(2, 1, 4)
Forecast Period: Q1-2020 to Q1-2022 | Region: U.S. Midwest
Training
Test
Forecasted
Magnitude (inches to the hundreth)
Year


Hail Average Magnitude Forecast with ARIMA(3, 1, 4)
Forecast Period: Q1-2020 to Q1-2022 | Region: U.S. South
Training
Test
Forecasted
Magnitude (inches to the hundreth)
Year


Hail Average Magnitude Forecast with ARIMA(0,1,2)
Forecast Period: Q1-2020 to Q1-2022 | Region: U.S. Northeast
Training
Test
Forecasted
Magnitude (inches to the hundreth)
Year


Hail Average Magnitude Forecast with ARIMA(3,1,1)
Forecast Period: Q1-2020 to Q1-2022 | Region: U.S. West
Training
Test
Forecasted
Magnitude (inches to the hundreth)
Year

ARIMA Model Findings

- **U.S. Mainland**
  - The ARIMA (4,2,4) model was able to explain 12% of the variability
  - Did not produce a reliable forecast → RMSE (0.17) > STD (0.12)
- **Midwest**
  - The ARIMA (2,1,4) model was able to explain 55% of the variability
  - Produced a reliable forecast → RMSE (0.09) < STD (0.12)
- **South**
  - The ARIMA (3,1,4) model was able to explain 31% of the variability
  - Did not produce a reliable forecast → RMSE (0.118) > STD (0.114)
- **Northeast**
  - The ARIMA (0,1,2) model was able to explain 21% of the variability
  - Did not produce a reliable forecast → RMSE (0.16) > STD (0.13)
- **West**
  - The ARIMA (3,1,1) model was able to explain 58% of the variability
  - Did not produce a reliable forecast → RMSE (0.33) > STD (0.30)

Conclusion

- Not very predictable on the regional or national level
- Removing outliers would create biased models that wouldn't necessarily translate into the real world

- **Next Steps:**
    - Changing the timeframe of the averages from quarterly to monthly
    - Introducing exogenous variables
    - Exploring other models such as SARIMA
    - Exploring additional events

Thanks!

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