NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Frequency Performance Report
July 2024

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Definitions

Box and Whisker Charts

A box and whisker chart represents distribution of observations in the sample. 50% of the data is contained inside the box and 50% of the data is contained outside the box. The box has both a light-grey and dark-grey colored section. These sections represent the lower and upper quartiles of the data. Both sections combined represent the interquartile interval (50% of the data). The line that splits the light-grey and dark-grey sections represents the median (middle) of the data. The data between the lower quartile (the bottom of the dark-grey box) and the lower whisker and the data between the upper quartile (the top of the light-grey box) and the upper whisker represents the other 50% of the data. The length of the whiskers is determined by 1.5 times the interquartile range. That means that the whiskers will reach the values that are furthest from the center while still being inside the distance of 1.5 times the interquartile range (upper and lower).

Any points that exist outside the whiskers are considered potential outliers. Those values represent anything beyond what we expected. The takeaway is that these values are weird days (not normal). We tend to focus on outliers, but we also look at changes in behavior from one quarter to the next.

Points that are considered new (part of the current quarter) are represented as orange crosses. They stand out because they have a different color and shape. The old data (not in the current quarter) is represented as blue dots. The old data is shown to help us see the differences. They are archived data points so we can see where we were and where we moved to.

Process Control Charts

These charts show a trend of the daily values of RMS. We try to call attention to *changes* in the trend (i.e., maybe a new process was introduced) that we can react to before things get out of hand. There are four different colors shown in these charts:

- **Red** represents a *shift*. For example, if the data wiggles up, then wiggles down, then down, then down again (instead of back up), the data is flagged as a *shift*. Many times, shifts are signaled by outliers.
- **Orange** represents an *outlier*. For example, if a data point goes further than expected, the data is flagged as an outlier. We don't focus on outliers, but they do signal outliers from time to time.
- **Blue** represents *in range*. If the data point is in range (between the upper and lower control limits), the data is behaving as expected (normal).

The *top* chart represents the process control chart itself. You'll notice a line across the top, across the middle, and across the bottom of the process control chart. The top and bottom lines represent the upper and lower control limits. These limits are calculated based on three standard deviations above and below the average. The values inside the band between the lower and upper limits represent a typical performance of the RMS. The middle line represents the average. There are two supporting charts provided below the process control charts for each interconnection (middle and bottom).

The *middle* chart represents the moving range. This shows the difference between one point and the next. It tends to highlight outliers for us as well.

The *bottom* chart represents data from the past five quarters. It provides a zoomed-in view so we can see shifts, outliers, and trends more clearly. Due to the smaller window of data (5 quarters as opposed to

3 years), this chart may show shifts and/or trends that are not identified in the process control chart. In this case, the shifts and/or trends are important to note but may not show up on the process control chart. So, there are multiple reasons for having a smaller window of data for interrogation.

The Western Interconnect has maintained a small oscillation, which is not as defined as Hydro Quebec, but shows a definite trend with seasonality. We don't normally draw any conclusions from the Hydro Quebec chart other than seasonality since their RMS is much smaller than the other interconnections. They control RMS very tightly. In the winter, Hydro Quebec experiences their largest load (cycling down of RMS).

Eye Charts

These charts plot the same RMS data in radial form. The radial view allows us to compare years, quarters, and seasons a bit easier than we could in the process control charts.

- The yellow line represents the epsilon value for the interconnect in question.
- The chart follows the year in a clockwise fashion, so the 12:00 mark represents January 1st.
- The maximum and minimum of the x and y axes for each interconnection represents 1.5 times their epsilon value. This was an effort to make the Eastern Interconnection RMS shape more clearly represent a circle and the Western Interconnection RMS shape more clearly represent the seasonal effects which occur from December to April (football shape).

The Eye chart is the best way to view the daily RMS data for Hydro Quebec. The different years and colors truly emphasize how their data is weather-driven. Year after year, their data will be different. The point at which winter comes will vary from year to year, so much of their variability depends on the load demand. In winter, their load is high, which causes lower variability in their data.

Time Error (Sam Rugel) Charts

These charts utilize the average frequency data to show average frequency error as well as calculate time error.

The *top* chart represents average frequency error itself. The *middle* chart represents the moving range, which shows the difference between one point and the next. The *bottom* chart utilizes the average frequency to represent the accumulated weekly time error. Each stripe represents one full week of data, so we can see how much time error we accumulate on a weekly basis.

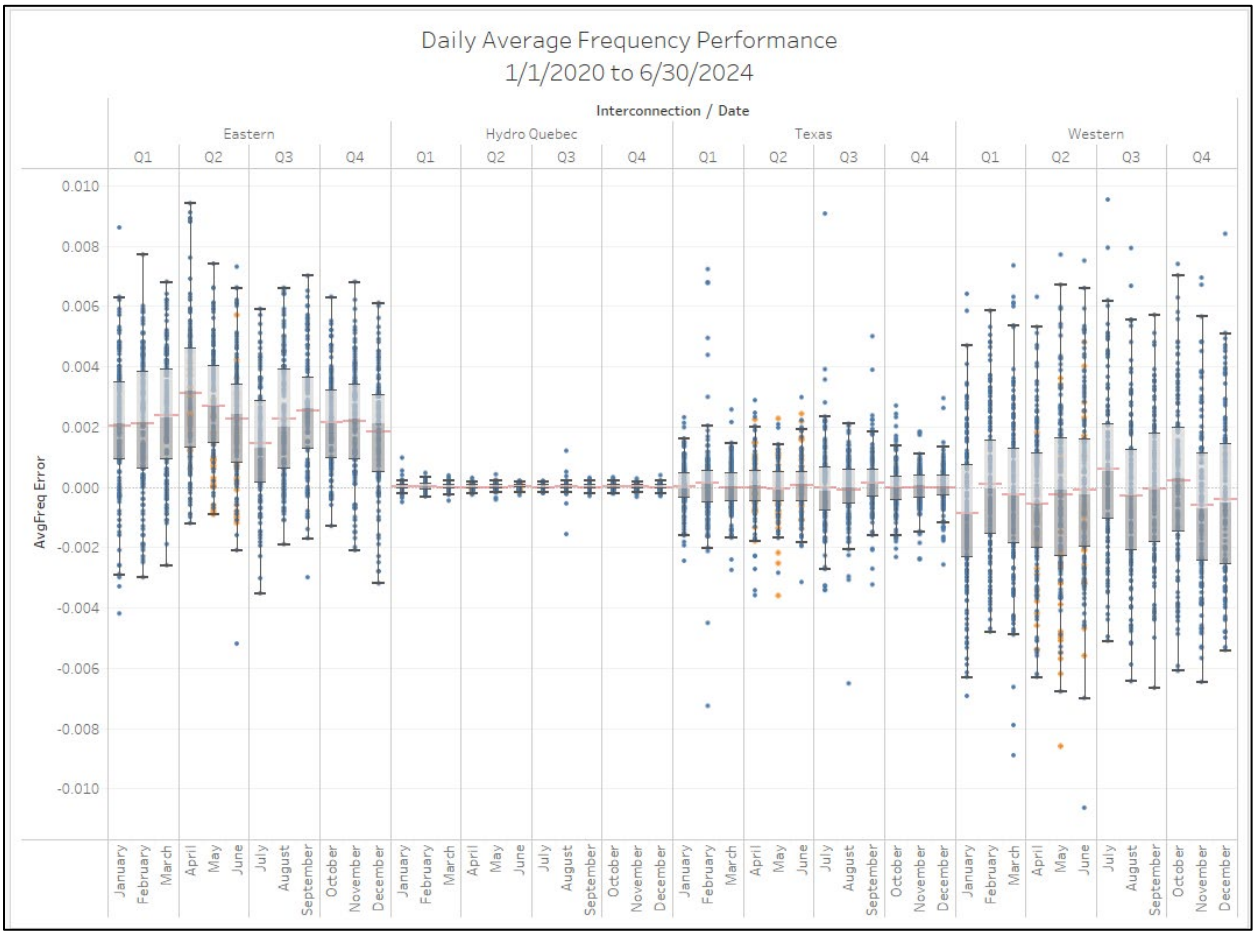
For Hydro Quebec, anything out of the normal would throw their charts off. They payback so efficiently that it's really a stretch to find any issues in time error accumulation.

Daily Average Frequency Performance

These box and whisker charts provide a 5-year rolling outlook. Each dot represents an individual day in each quarter. The quarters are shown across the top of each chart, and the months are shown across the bottom of the chart (for each quarter). This provides the distribution for each month and allows you to see the changing patterns from month to month. Since the previous quarter is always the objective, we're looking to see if we improved frequency performance throughout the quarter. You can compare the newer data (orange crosses) with the older blue dots from previous years (in the 5-year span) in that quarter.

All Interconnections

This chart is a summary showing everyone together. It highlights the frequency error that each interconnect is centered around. Except for the Eastern interconnect, the other interconnections are centered around 0 Hz. The Eastern interconnect tends to run ~2.4 mHz high each quarter.

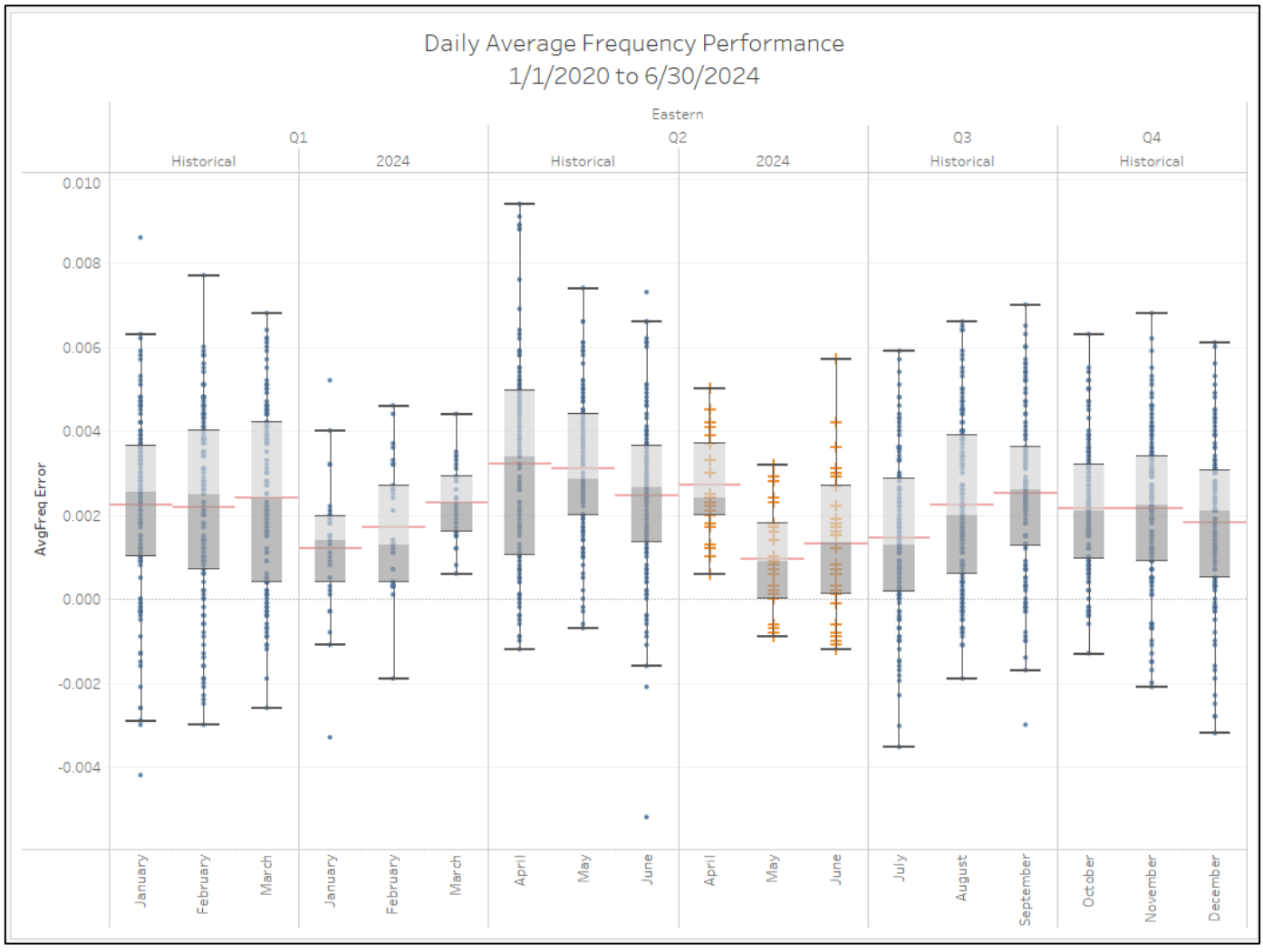


Next, we'll look at each of the interconnections separately to see if we can glean any useful or actionable information.

Eastern Interconnect

Looking at the new data, here are some takeaways:

- Average frequency error improved in all months over historical years.
- Improved variability in the IQR (box) in **April** over historical years.
- Improved variability in the whiskers in **April** and **May** over historical years.
- No outliers.

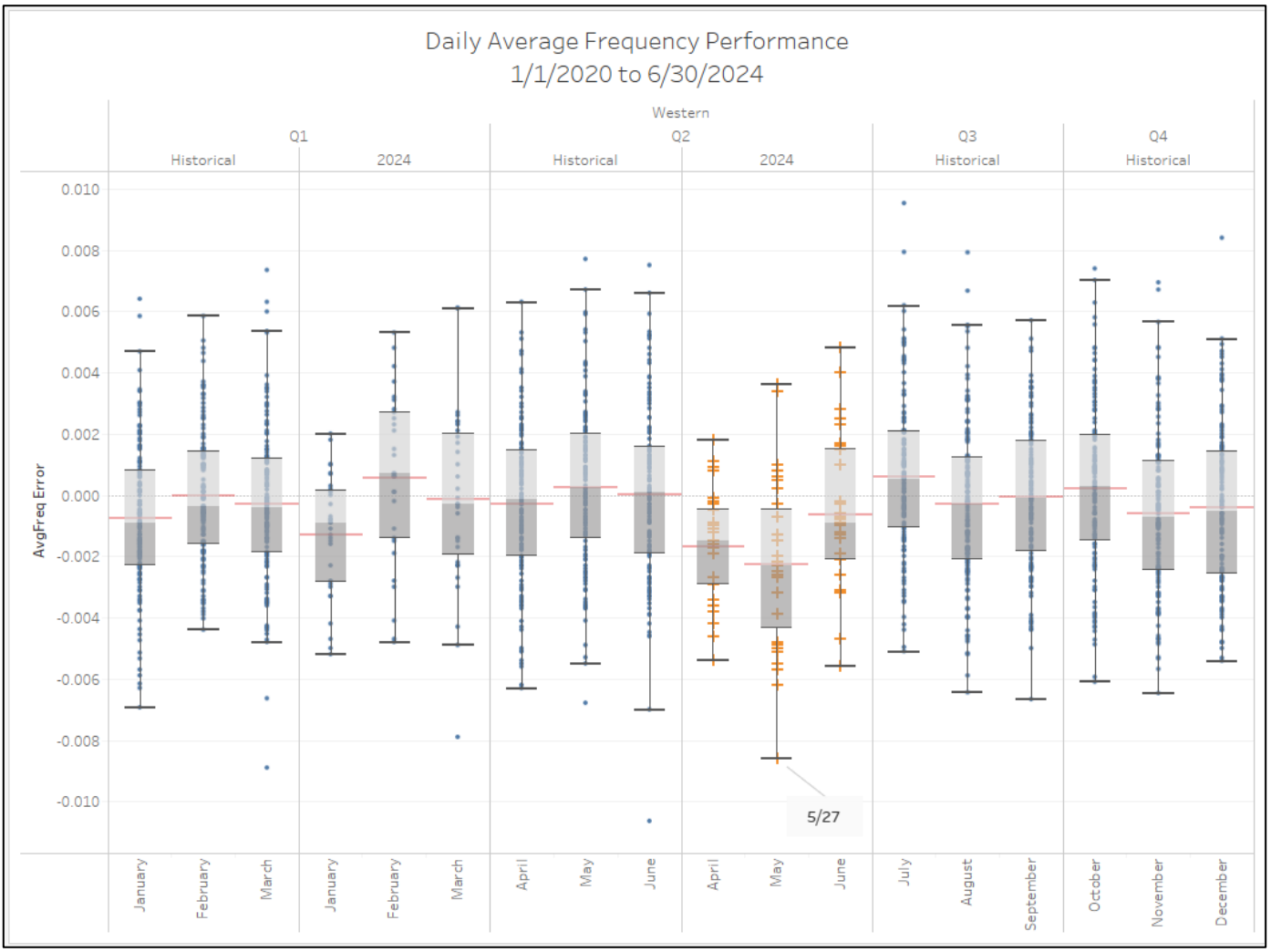


Eastern Reps: Troy Blalock, David Kimmel, Bill Henson

Western Interconnect

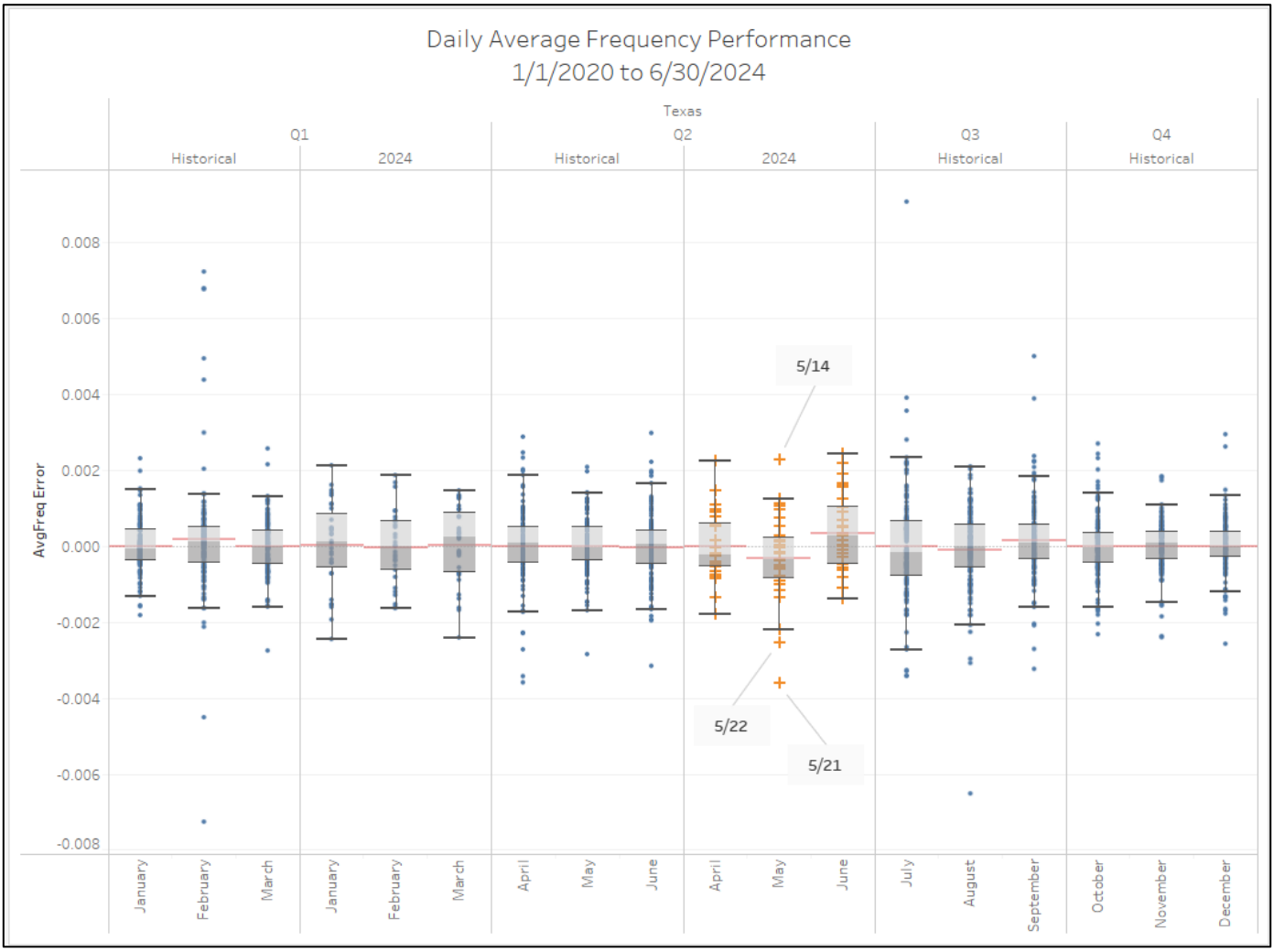
Looking at the new data, here are some takeaways:

- Lower average frequency error in all months compared to historical years.
- Improved variability in the whiskers in **April** and **June** compared to historical years.
- **April** and **May** seemed to be tougher months for the WI last quarter.
- One possible outlier in **May**.



Western Reps: Calvin Dacus, Greg Park, Sam Rugel

Texas



2/15/2021 excluded due to an extreme outlier

Texas Reps: Luis Hinojosa, Abhi Masanna Gari, Nitika Mago

Looking at the new data, here are a few takeaways:

- **Lower** average frequency error in **May** over historical years.
- **Higher** average frequency error in **June** over historical years.
- Three outliers (explained below):
  - **5/14** (Avg Freq Error = 0.00227):

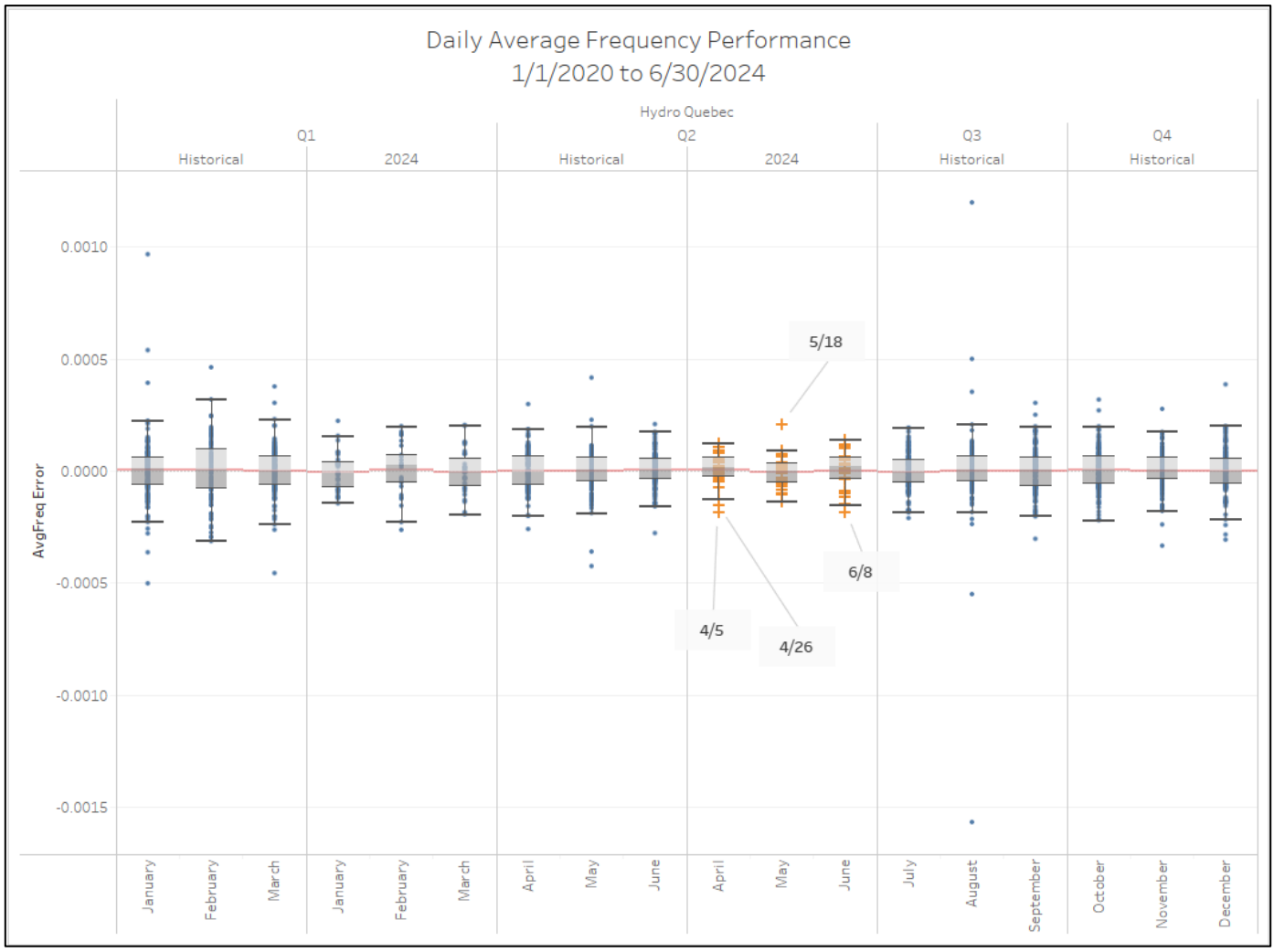
- Between 07:00 and 08:15, the frequency remained at or above high deadband due to steep solar up ramp and load over forecast. The solar generation ramped up by approximately 11000 MW during this time.
- Between 20:30 and 21:50, the frequency remained at or above high deadband due to load over forecast and wind under forecast.

- **5/21** (Avg Freq Error = -0.00361):
  - Between 06:50 and 07:10, the frequency remained below low deadband and declined to 59.955 Hz due to load under forecast and wind over forecast. Wind generation ramped down by approximately 1,000 MW during this time.
  - Between 15:44 and 15:54, the frequency remained below low deadband, and declined to 59.924 Hz due to load under forecast and steep solar ramp down. Solar generation ramped down by approximately 1000 MW.
  - There are several sustained intervals throughout the day where frequency remained below low deadband due to load under forecast and or solar/wind generation over forecast.
- **5/22** (Avg Freq Error = -0.00253):
  - Between 07:40 and 08:00, the frequency remained below low deadband and declined to 59.946 Hz due to wind over forecast. The wind generation ramped down by approximately 2,000 MW.
  - Between 12:00 and 12:10, the frequency remained below low deadband and declined to 59.943 Hz due to steep solar ramp down. The solar generation ramped down by approximately 900 MW.
  - At approximately 18:36, the frequency declined to 59.910 Hz due to a loss of ~1,400 MW of thermal generation.

Hydro Quebec

Looking at the new data, here are some takeaways:

- Tighter average performance in all months over past years.
- Four outliers.



HQ Reps: Dominic Richard, Guillaume Bouchard, Hubert' 'Nolet Côté

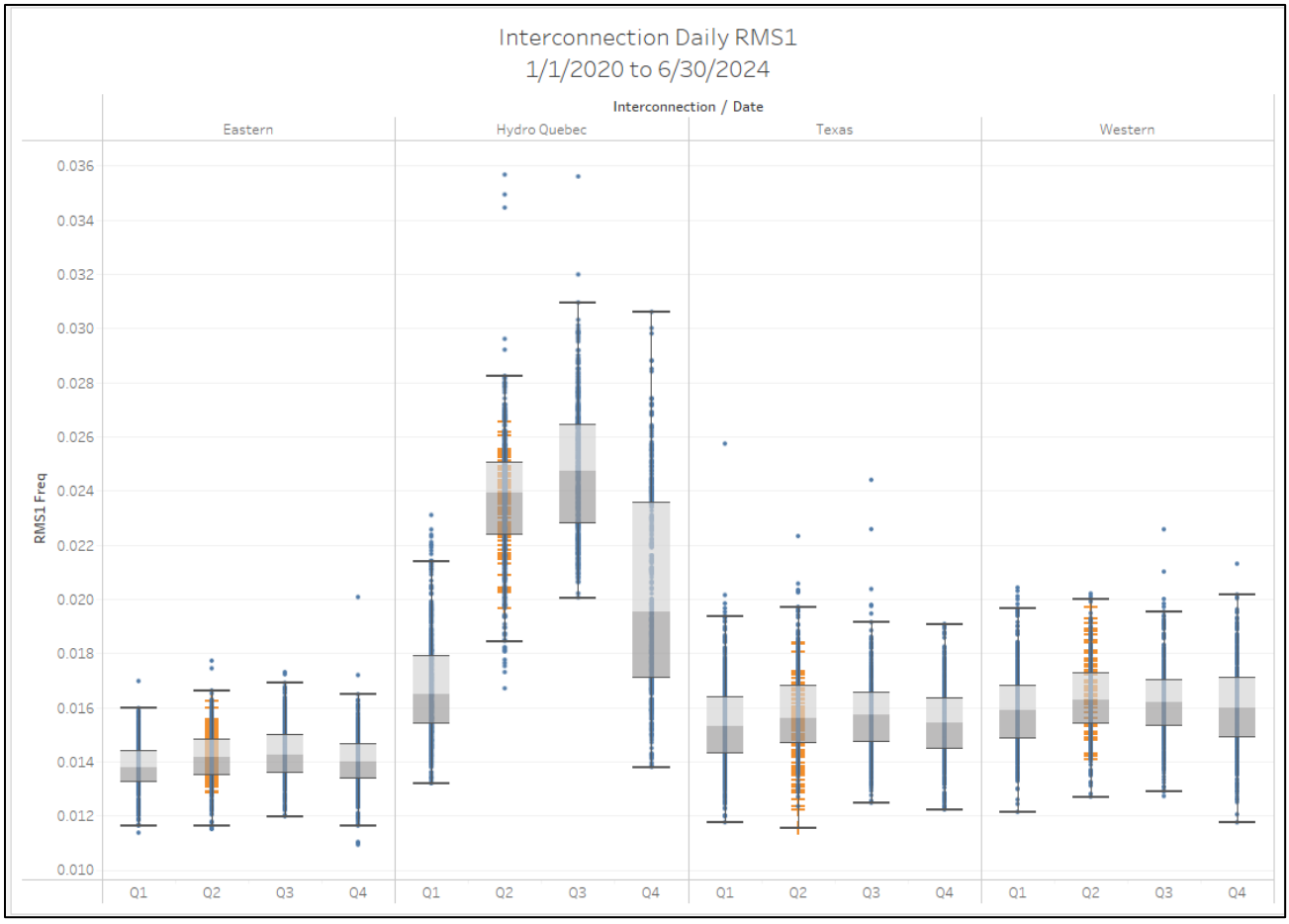
Daily RMS1 Performance

These charts deal with the same type of data, but we're looking at the RMS (root mean squared) frequency for each interconnect. That's an average frequency, combined with a wiggle. Basically, what is that range of frequency as it moves up and down on any given day? Do we have some stability?

All Interconnections

This chart is a summary showing everyone together.

- Good performance.
- No outliers.



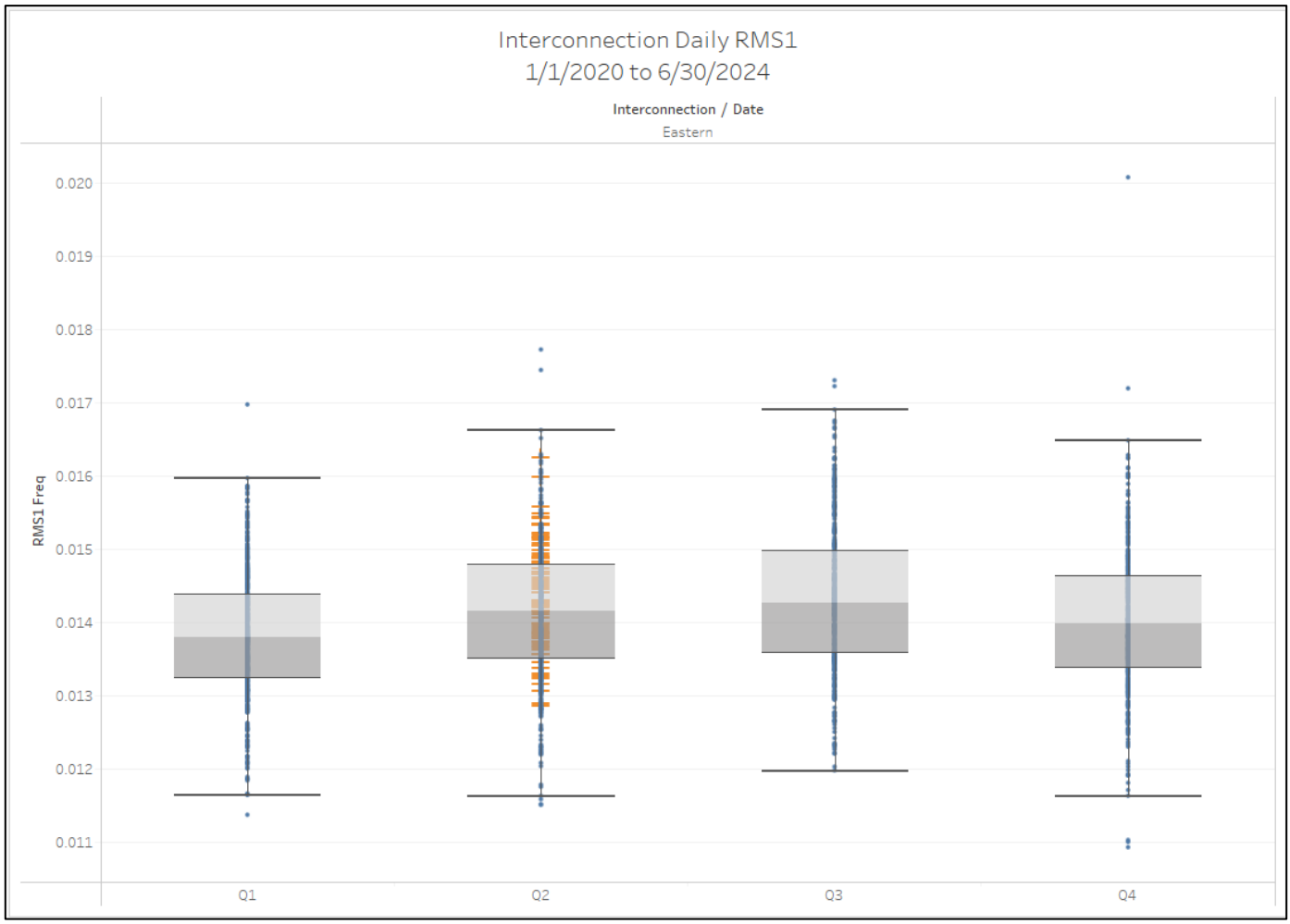
2/15/2021 excluded due to an extreme outlier (Texas)

Next, we'll look at each of the interconnections separately to see if we can glean any useful or actionable information.

Eastern Interconnect

Looking at the new data, here are some takeaways:

- Good performance.
- No outliers.

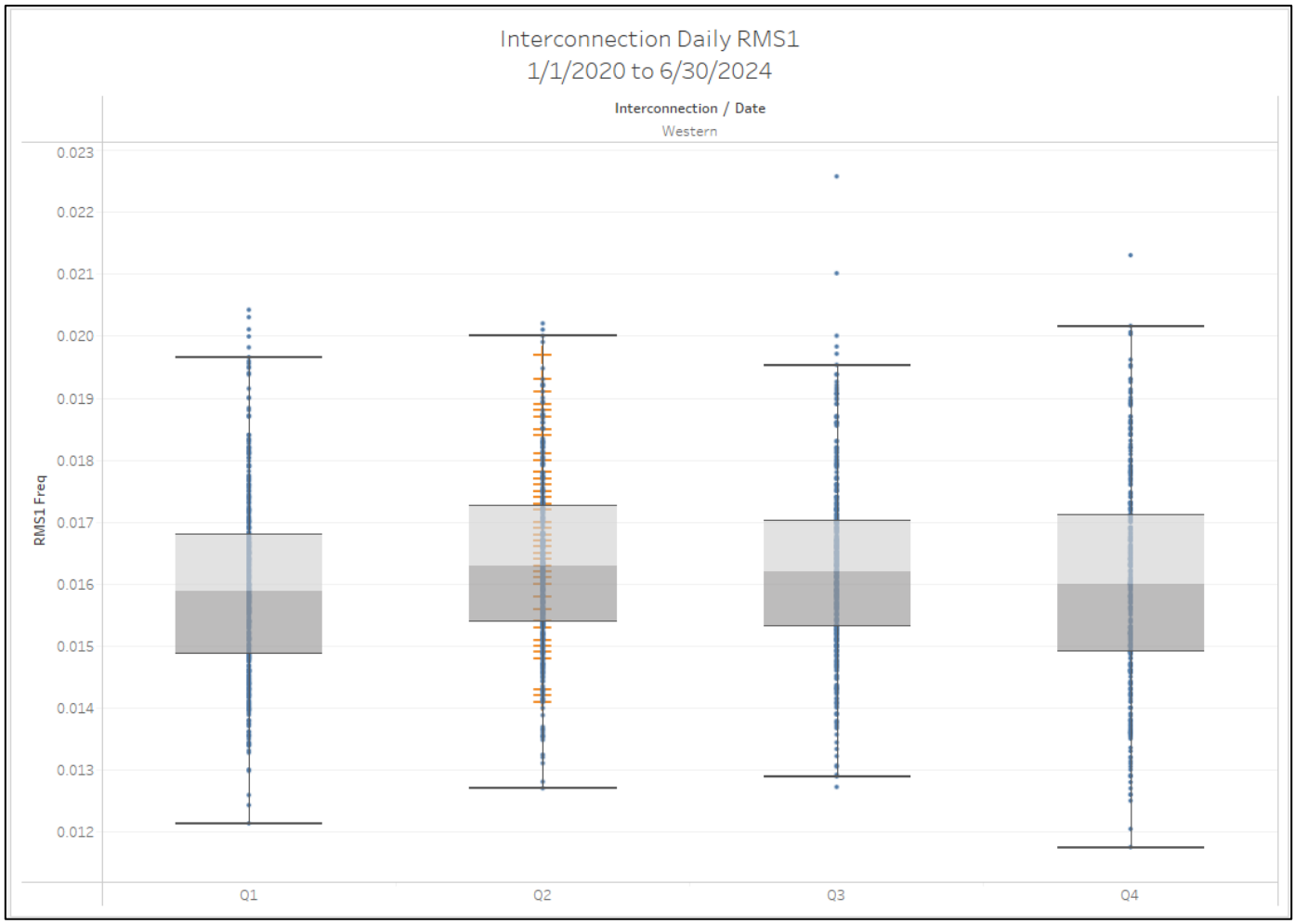


Eastern Reps: Troy Blalock, David Kimmel, Bill Henson

Western Interconnect

Looking at the new data, here are some takeaways:

- Good performance.
- No outliers.

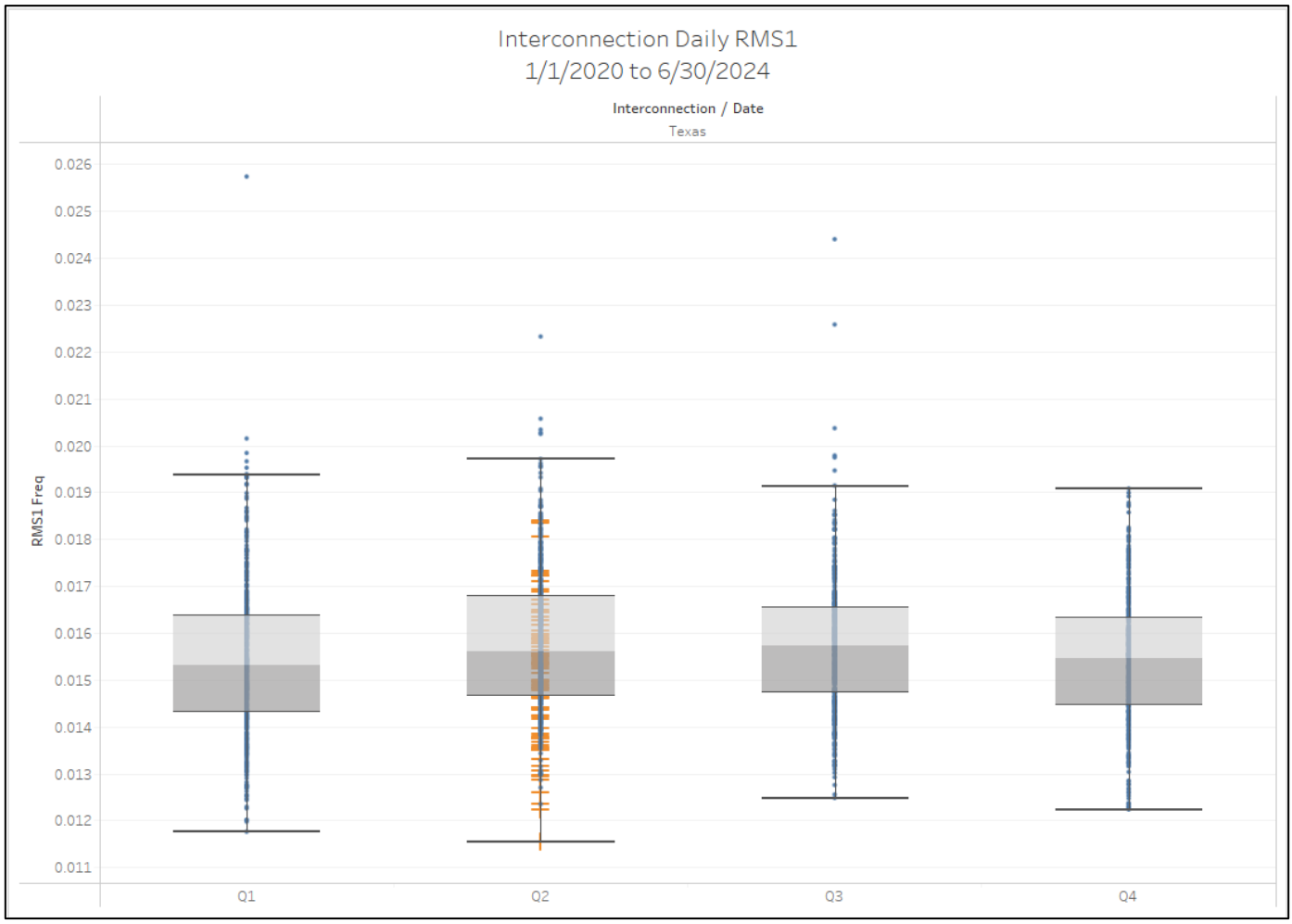


Western Reps: Calvin Dacus, Greg Park, Sam Rugel

Texas

Looking at the new data, here are some takeaways:

- Good performance.
- No outliers.

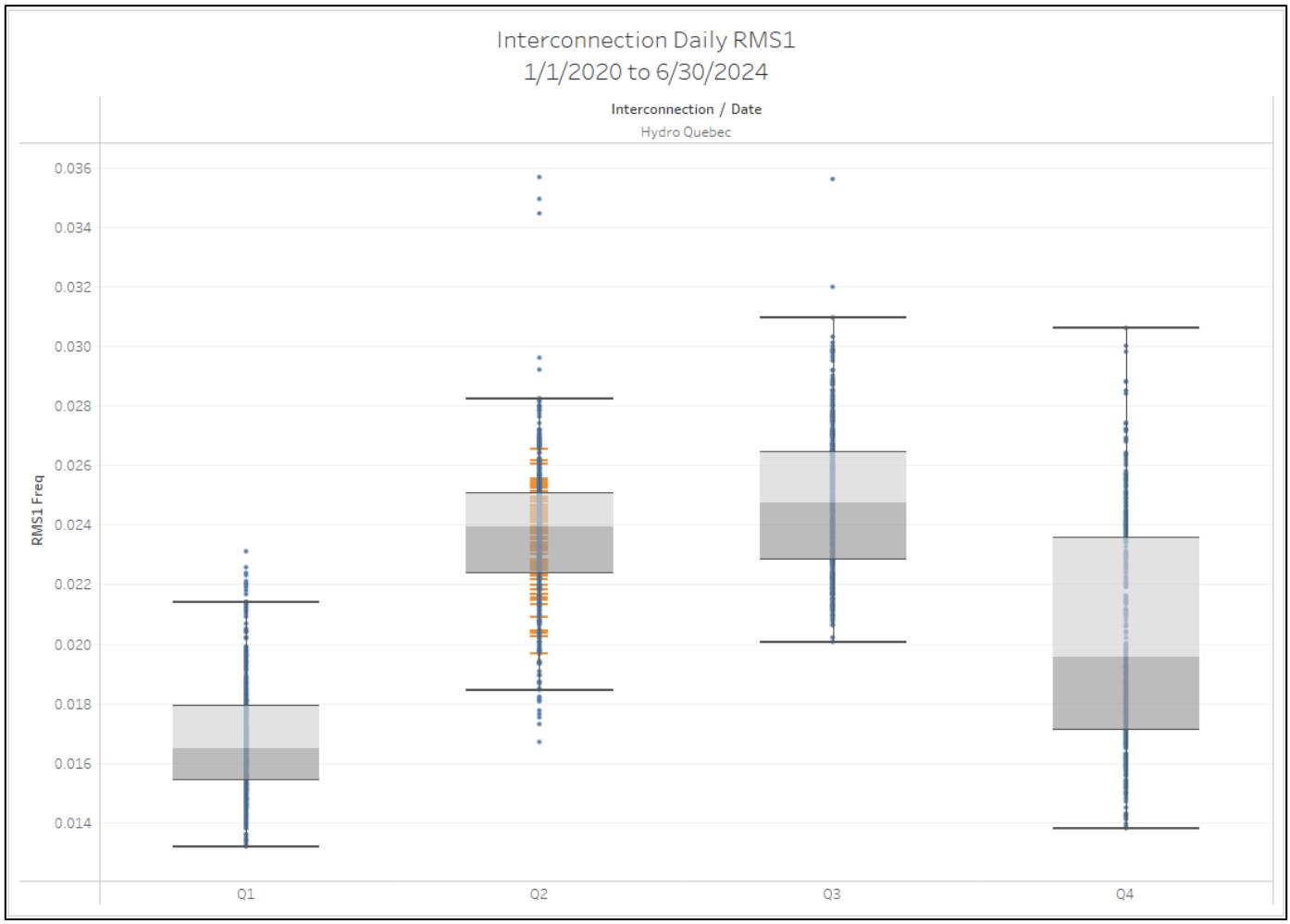


Texas Reps: Luis Hinojosa, Abhi Masanna Gari, Nitika Mago

Hydro Quebec

Looking at the new data, here are some takeaways:

- Good performance.
- No outliers.



HQ Reps: Dominic Richard, Guillaume Bouchard, Hubert' 'Nolet Côté

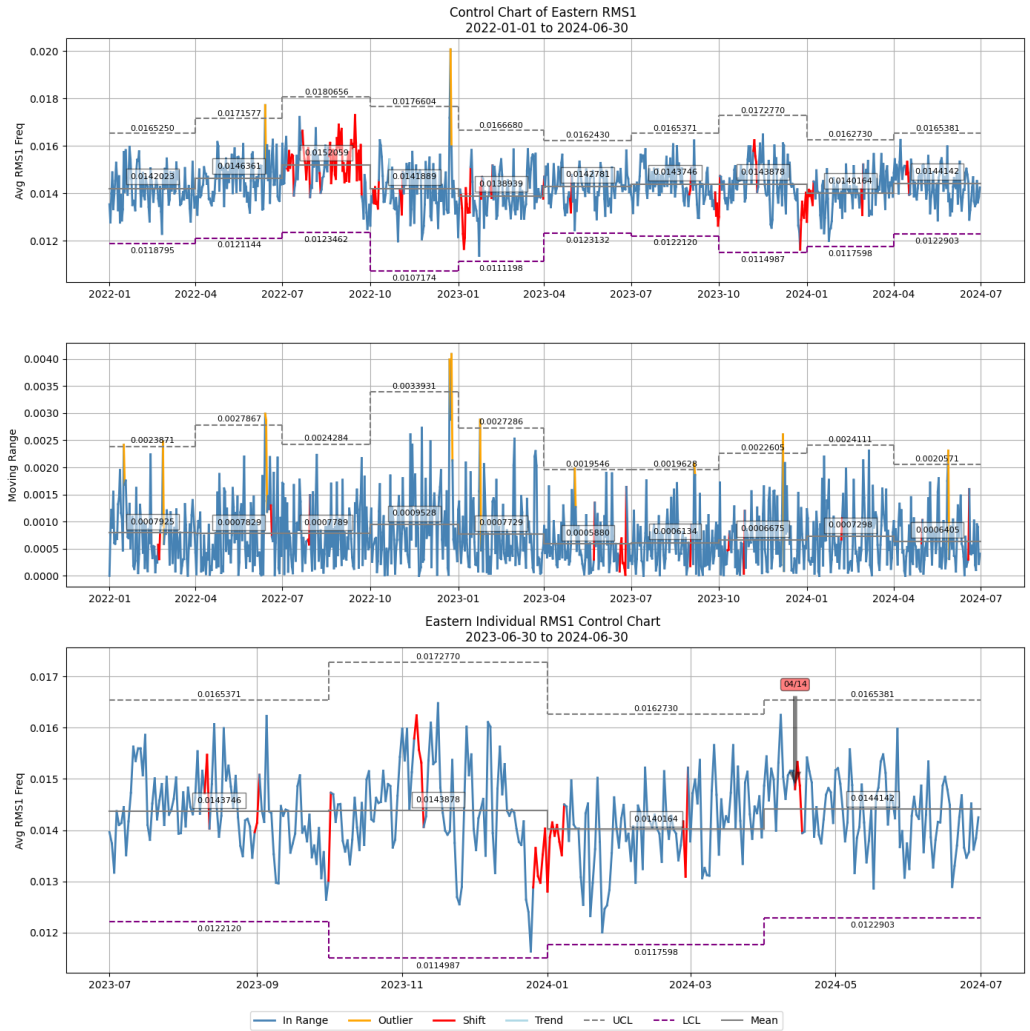
Process Control Charts

These charts show a trend of the daily values of RMS. We try to call attention to changes in the trend (i.e. shifts, maybe a new process was introduced).

Eastern Interconnect

Looking at the new data, here are some takeaways:

- Quiet operation. Good performance.
- There appears to be a shift beginning on 4/15.

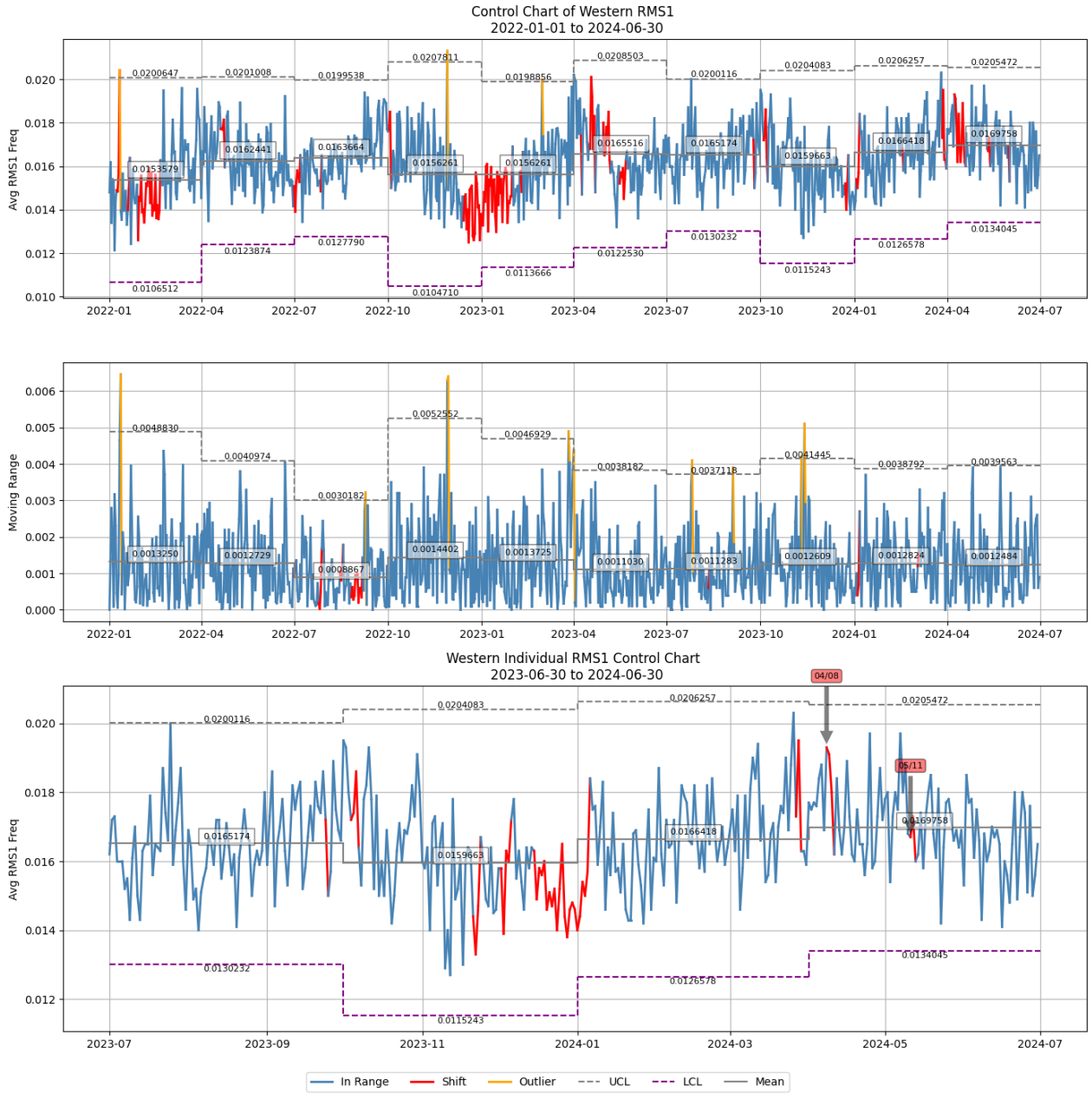


Eastern Reps: Troy Blalock, David Kimmel, Bill Henson

Western Interconnect

Looking at the new data, here are some takeaways:

- Typical downward trend we've seen year-over-year during last quarter.
- There appears to be two shifts beginning on 4/8 and 5/11.

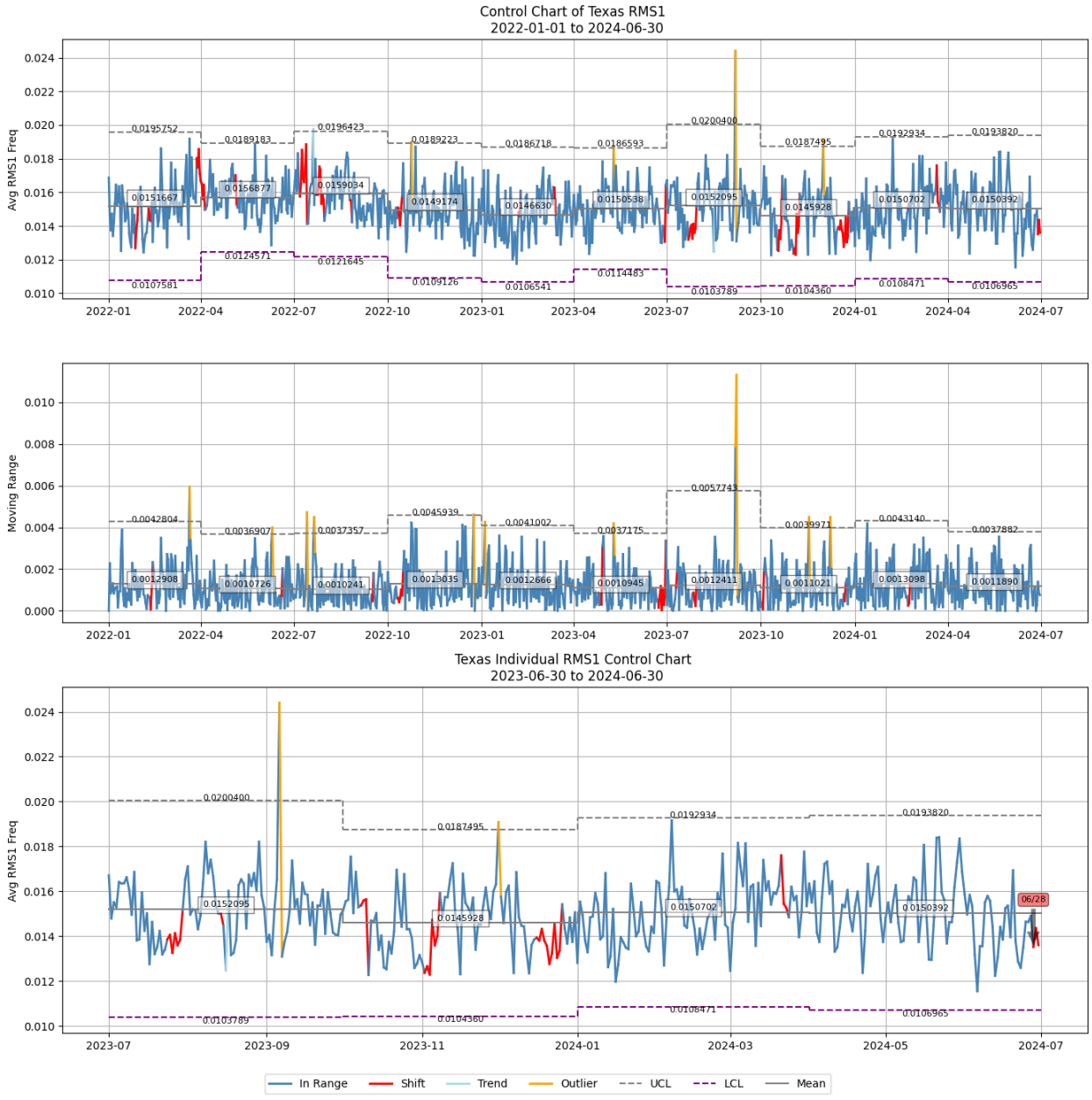


Western Reps: Calvin Dacus, Greg Park, Sam Rugel

Texas

Looking at the new data, here are some takeaways:

- Quiet operation. Good performance.
- There appears to be a shift that begins on 6/28.

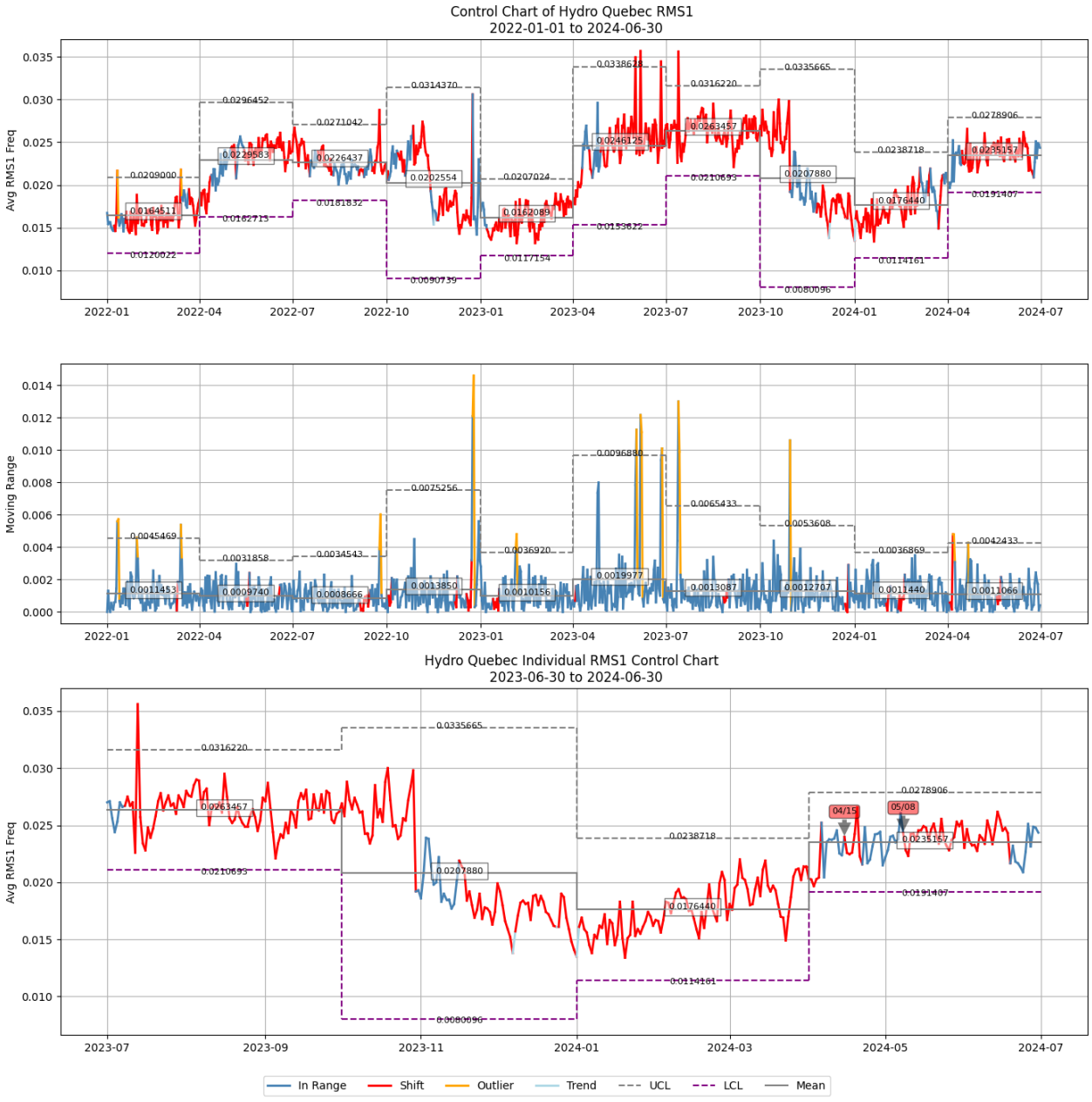


Texas Reps: Luis Hinojosa, Abhi Masanna Gari, Nitika Mago

Hydro Quebec

Looking at the new data, here are some takeaways:

- Typical seasonal behavior last quarter (higher average RMS1 frequency).
- Two shifts are noted, beginning on 4/15 and 5/8. However, this is normal behavior.



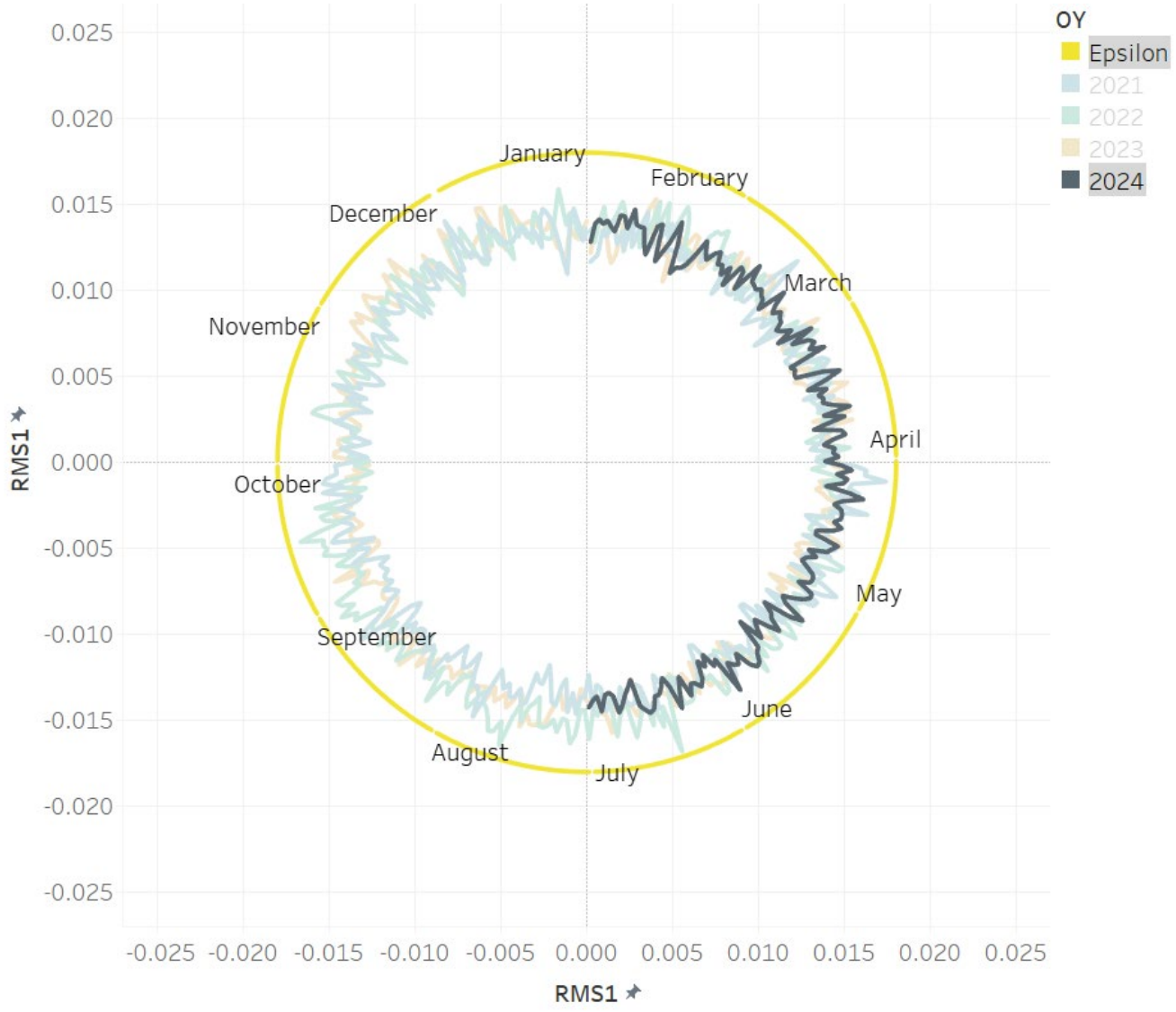
HQ Reps: Dominic Richard, Guillaume Bouchard, Hubert' 'Nolet Côté

Eye Charts

These charts represent the same data (daily RMS values) shown in the process control charts in radial form.

Eastern Interconnect

Quiet operation. Good performance.



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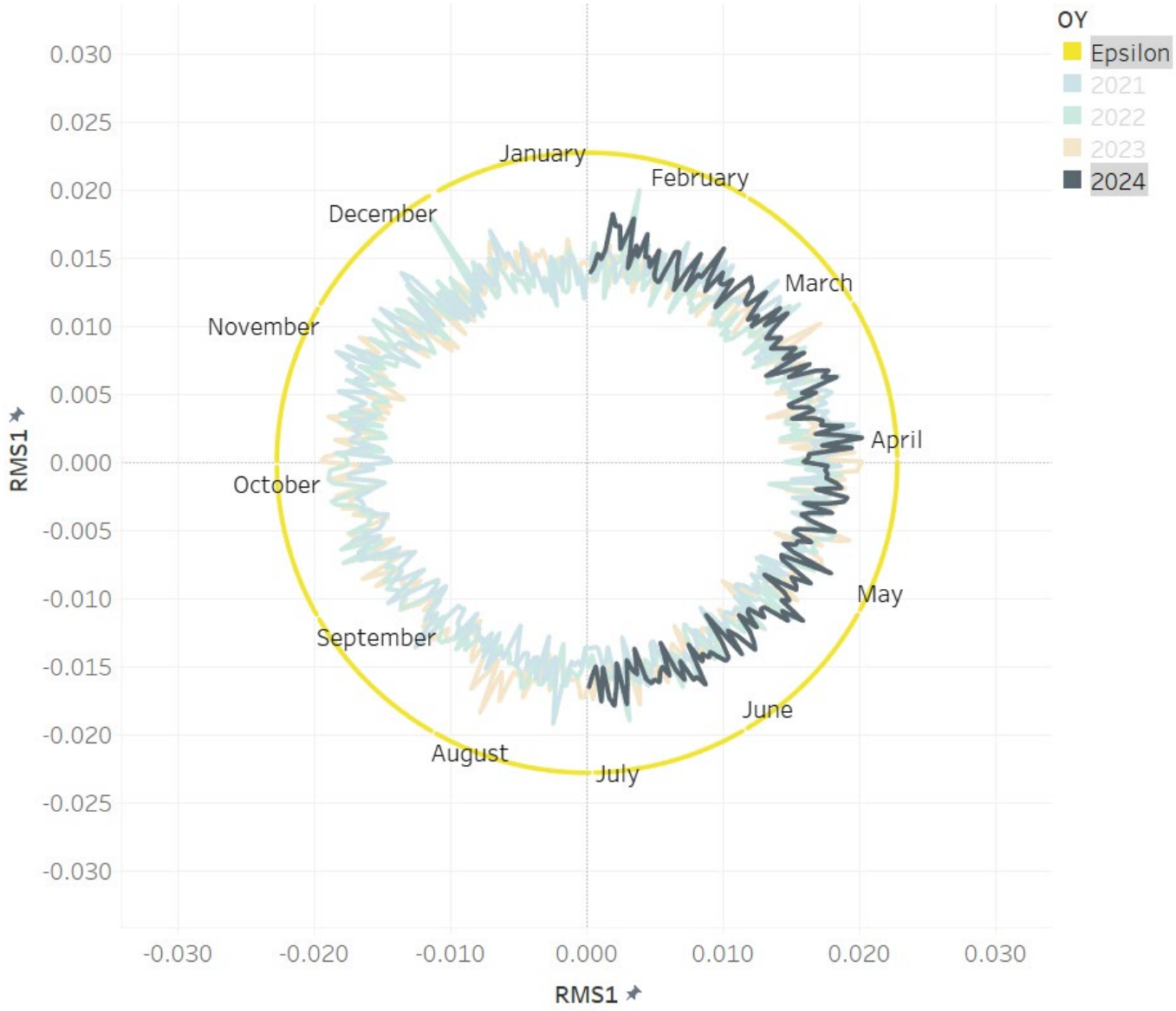
Western Interconnect

Quiet operation. Good performance.



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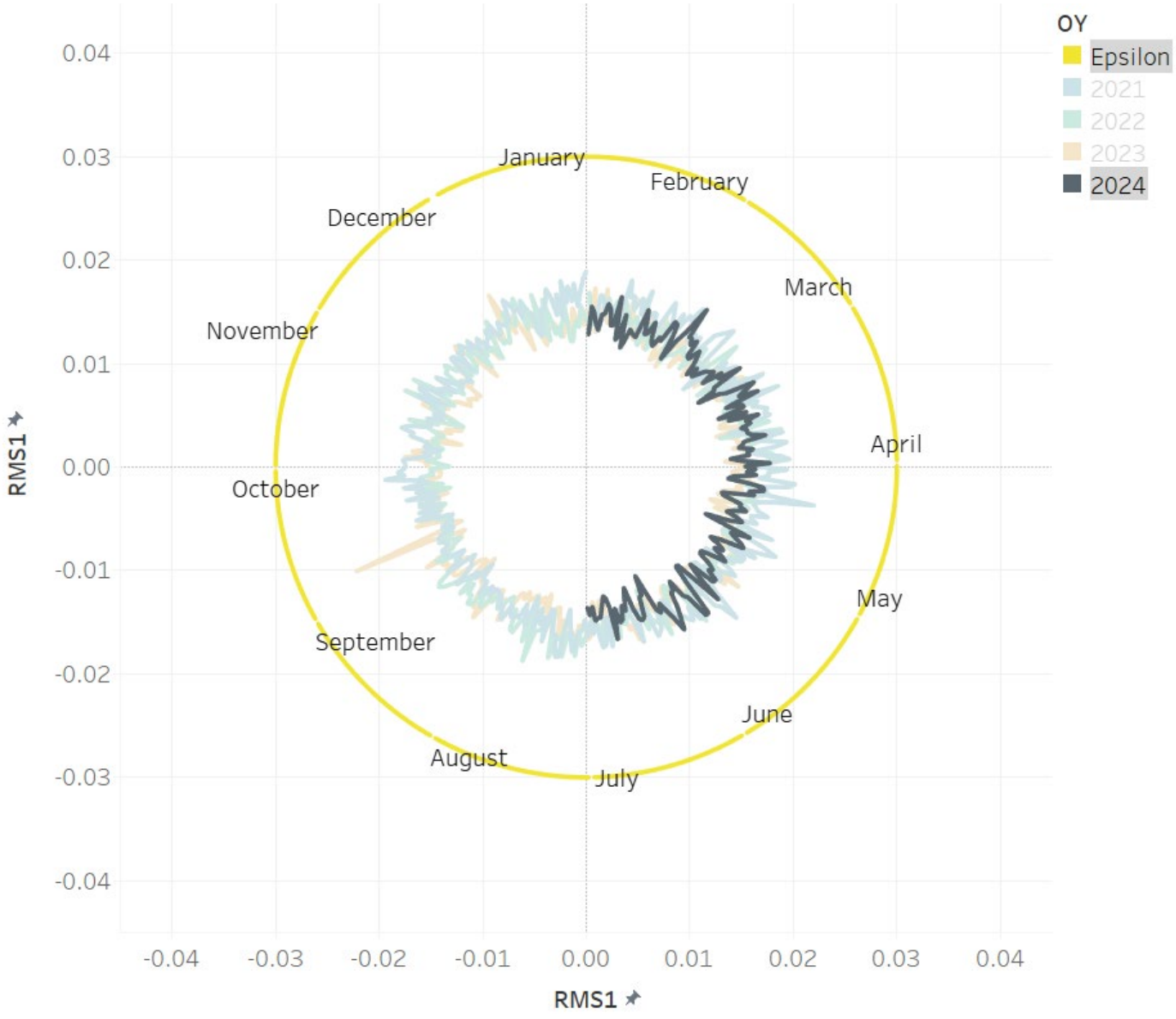
Texas

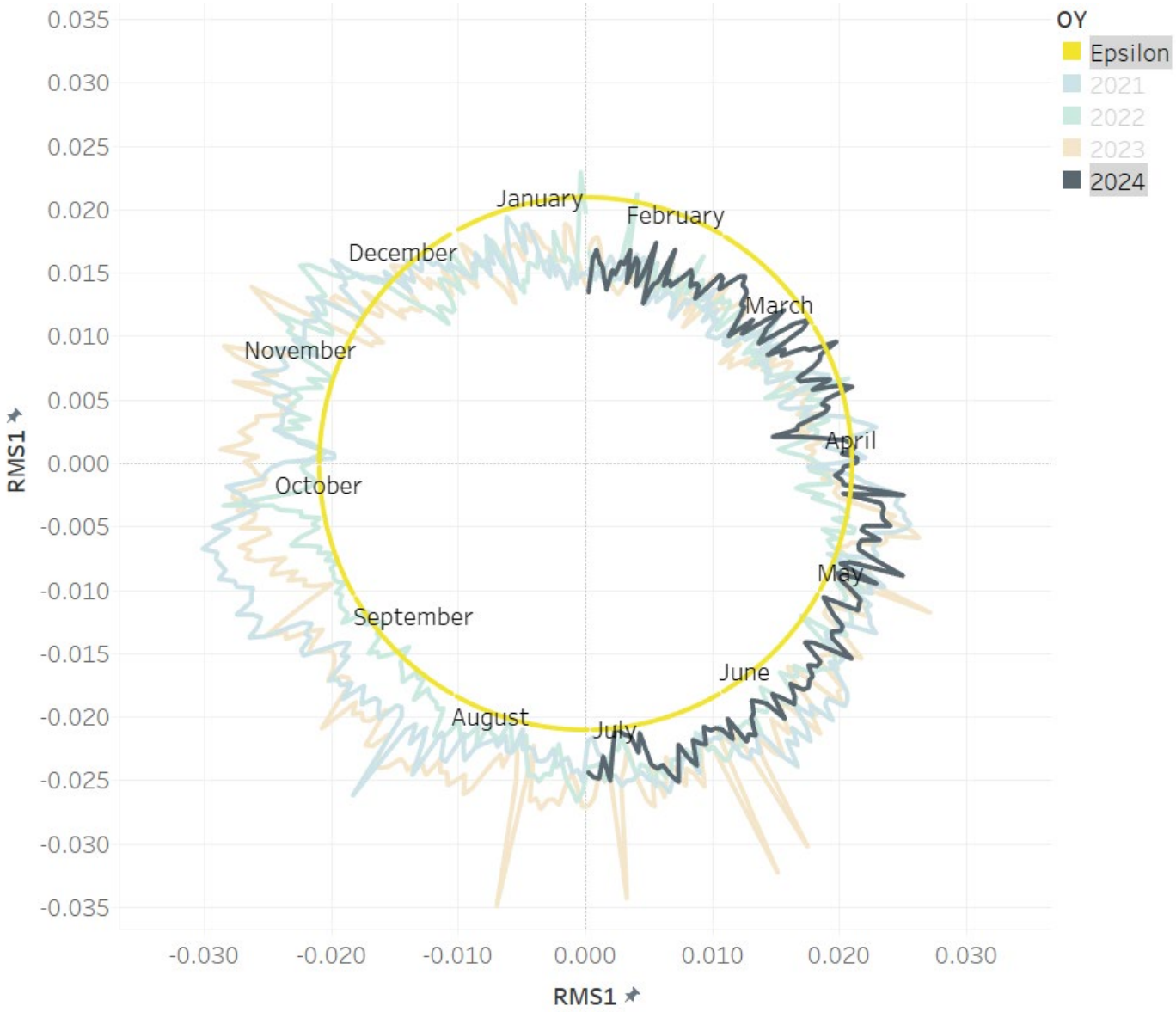
Quiet operation. Good performance.



Texas Reps: Luis Hinojosa, Abhi Masanna Gari, Nitika Mago

Hydro Quebec

Normal operation. Good performance.



HQ Reps: Dominic Richard, Guillaume Bouchard, Hubert' 'Nolet Côté

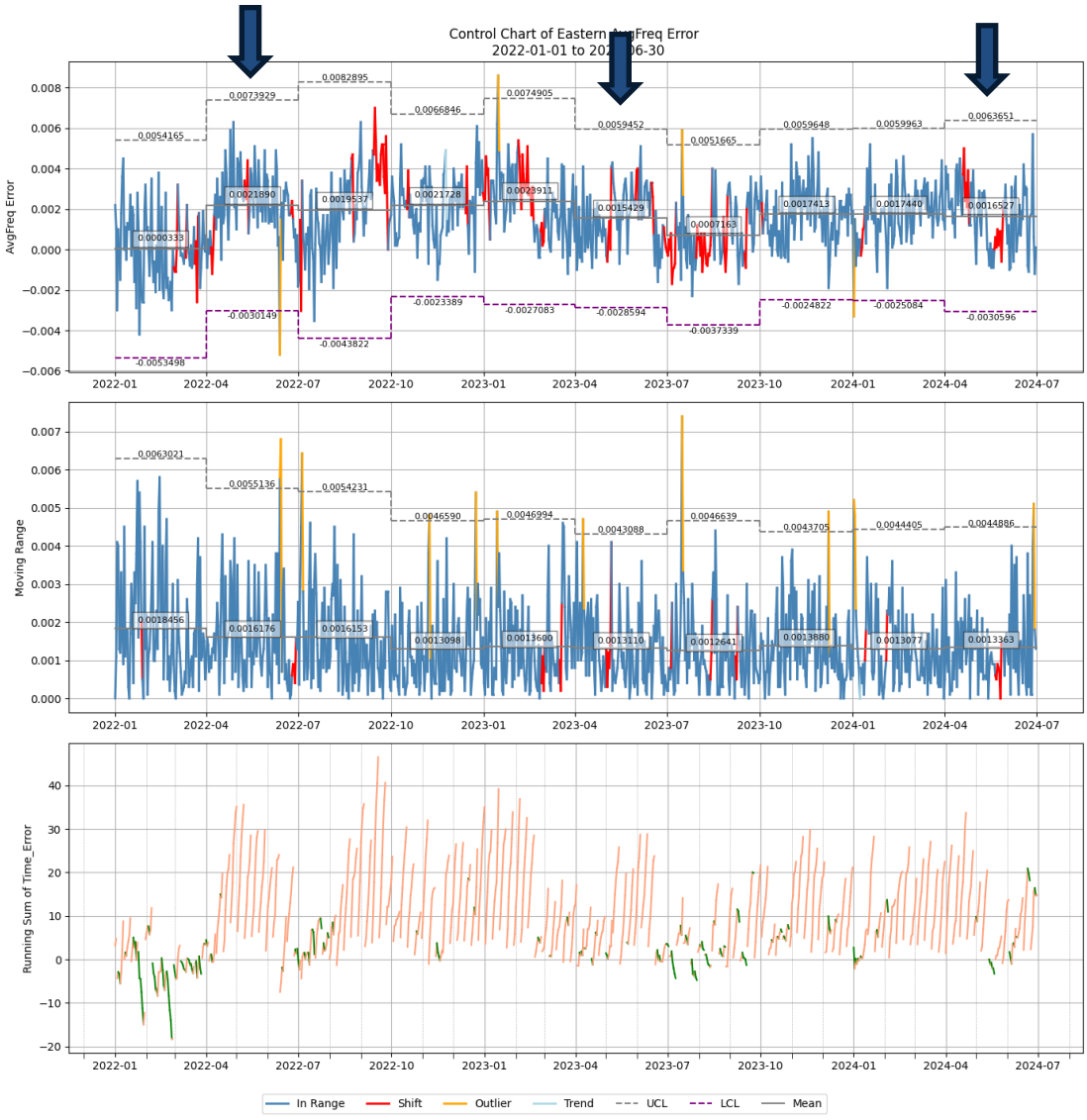
Time Error Charts

These charts represent average frequency error and how much time error we accumulated.

Eastern Interconnect

Looking at the new data, here are some takeaways:

- 2022 and 2023 showed *positive* arcs during this same period. The arc was *negative* last quarter.
- We slowed down in TE accumulation in both the middle and end of **May**.

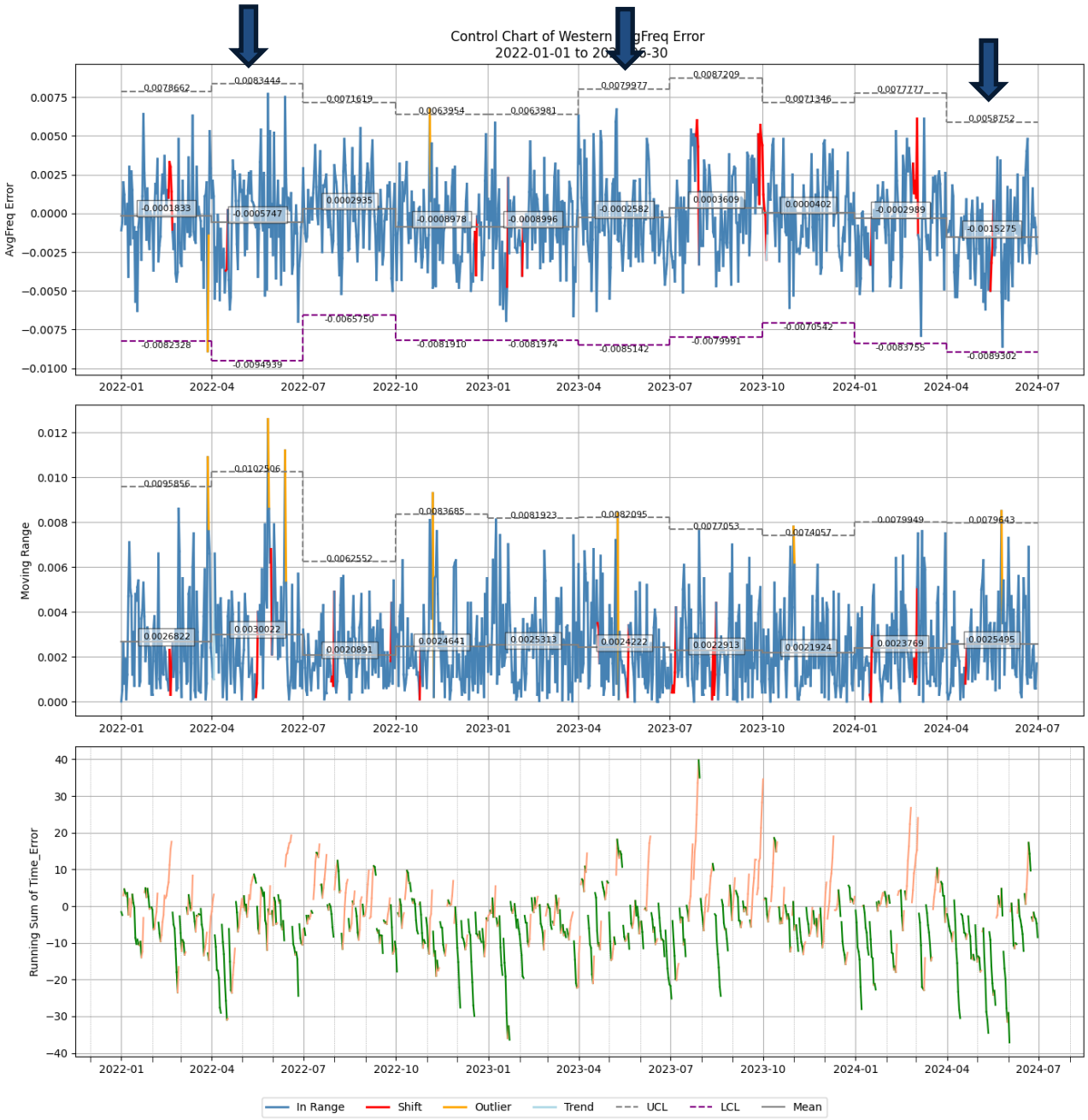


Eastern Reps: Troy Blalock, David Kimmel, Bill Henson

Western Interconnect

Looking at the new data, here are some takeaways:

- Normal behavior. The control limits have been wider during this period in previous years.
- Lots of negative TE accumulation last quarter. Frequency data within range.

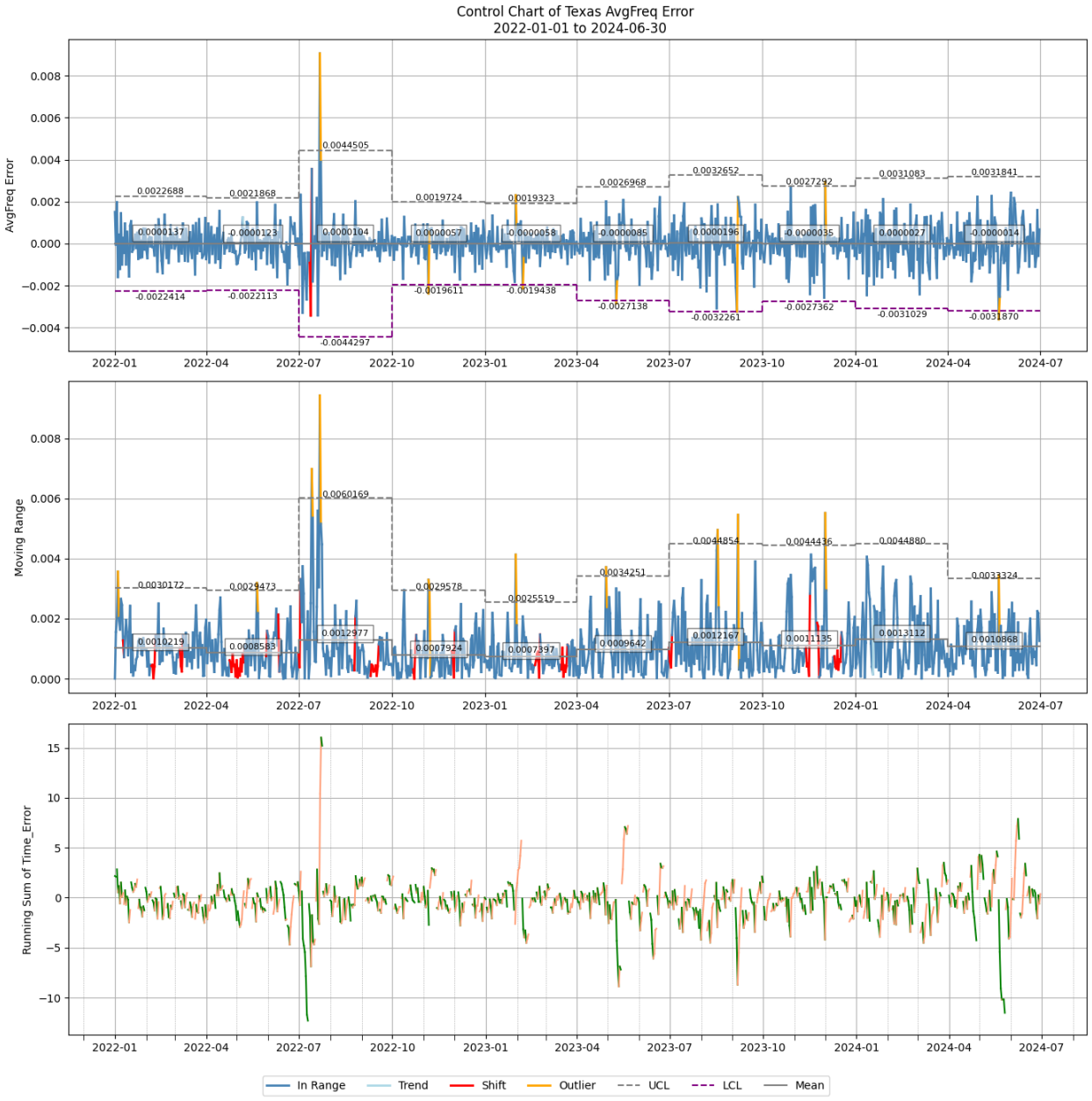


Western Reps: Calvin Dacus, Greg Park, Sam Rugel

Texas

Looking at the new data, here are some takeaways:

- Normal behavior. The control limits were wider last quarter than previous years in this period.
- Frequency data within range.

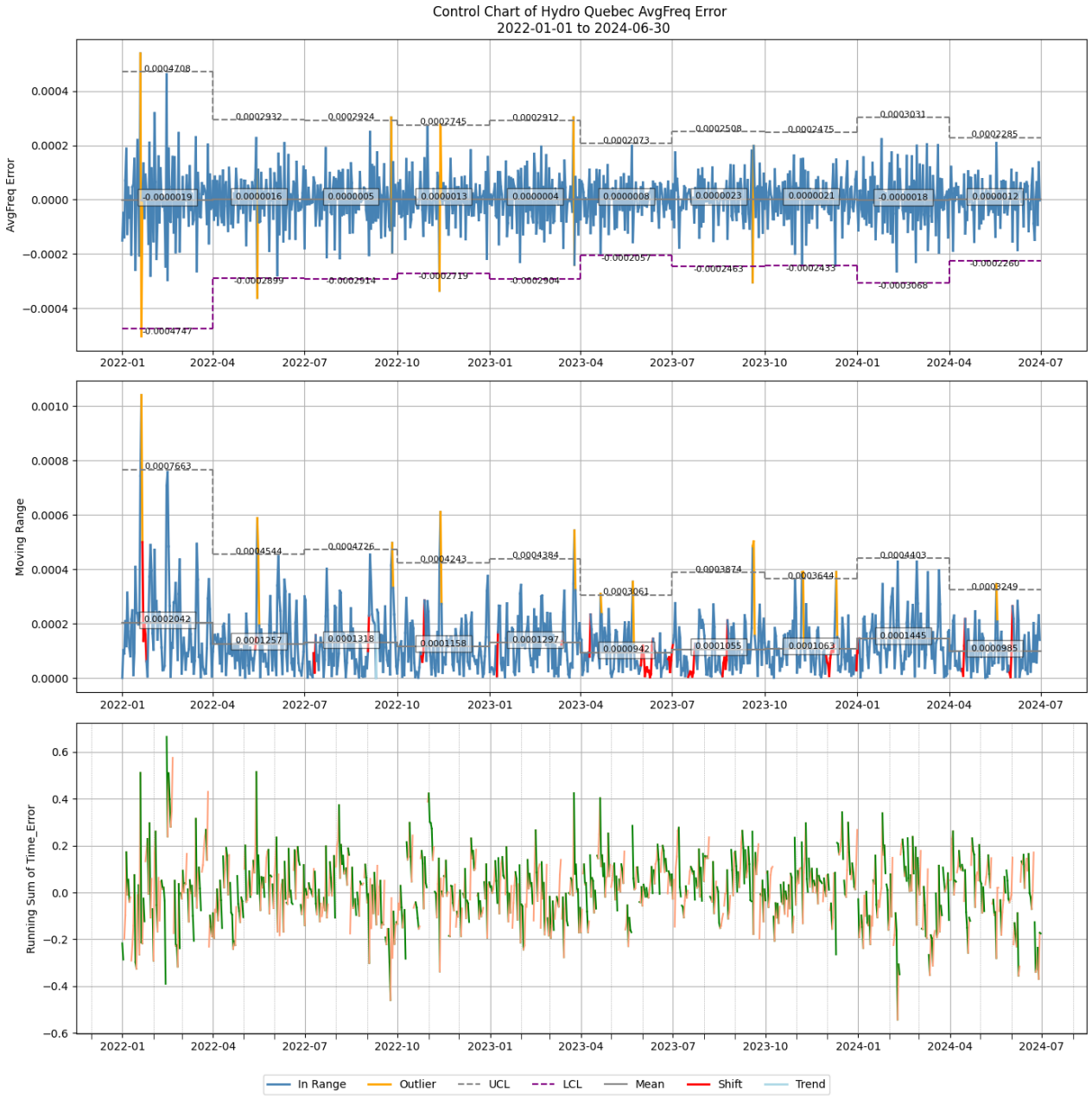


Texas Reps: Luis Hinojosa, Abhi Masanna Gari, Nitika Mago

Hydro Quebec

Looking at the new data, here are some takeaways:

- Normal seasonal behavior. No issues to report.
- Frequency data within range.



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