Assessing the quality of GNSS stations in the NOAA Continuously Operating Reference Station Network using IGS products

Amy Whetter (amy.whetter@noaa.gov) and Phillip McFarland
NOAA's National Geodetic Survey, Silver Spring, Maryland, USA
Tuesday, December 13th; 2:45 PM - 6:15 PM CST

G25D-0249

AGU FALL MEETING
Chicago, IL & Online Everywhere
12–16 December 2022

1. Summary

The NOAA Continuously Operating Reference Station Network (NCN) comprises roughly 1700 GNSS ground tracking stations. Nearly all these stations are owned and operated by state departments of transportation, scientific institutions, and real-time network operators. The station operators contribute data to the NCN, which is managed by the National Geodetic Survey (NGS), in support of NGS's mission to define, maintain, and provide access to the U.S. National Spatial Reference System (NSRS). The NCN data are also used in NGS's Online Positioning User Service (OPUS), an online tool that allows users to obtain coordinates at their points of interest by submitting GNSS tracking data (i.e. RINEX files) through a user-friendly portal. However, since NGS does not own most stations in the NCN there is significant heterogeneity in monumentation, equipment, and site maintenance across the network. This heterogeneity among stations can affect the end coordinates users of the NSRS and OPUS receive. Recently, NGS has developed a system to assess the overall quality of each station in the NCN. Within this system, long term (years) and short term (weeks) stability of the stations are addressed. These metrics are evaluated using data produced by our daily network monitoring tool. This monitoring tool uses IGS products (rapid orbits, RINEX, and IG[S,b]YY.snx) to estimate the coordinates of all ~1700 stations each day. In this work, we describe the strategy used to assess NCN station quality and present results from applying the developed metrics to daily position estimate residuals.

2. Use Case

Station A,B,C,D are all comparable stations with our current selection methods (data availability and distance) and leaves us unsure of which station to select. Using our method we can make a more informed selection. We see that Station B would be selected because it has the best combination of scores.

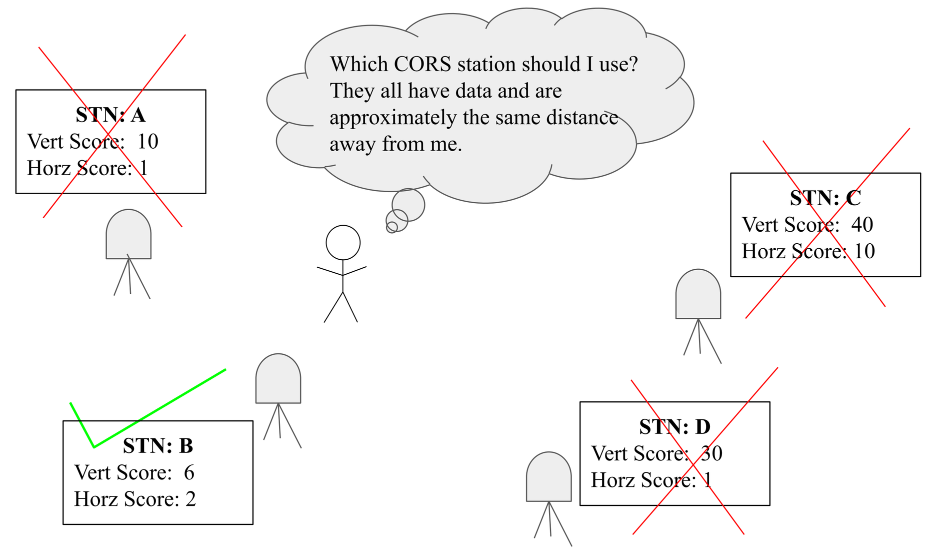


Figure 1: Schematic of CORS select use case.

3. Method

Developing the Algorithm

$$Daily\ Stability\ Score = \underline{\alpha}(W_1 * RMS_1 + W_2 * RMS_2) + \underline{\beta} * RMS_3$$

$$Where\ \alpha + \beta = 1$$

Weight parameters

$$k = \frac{\tan(\frac{\pi}{4})}{\tau}$$

The time at which W1 and W2 cross.

$$W_1 = 1 - \frac{2}{\pi}tan^{-1}(k\Delta t)$$

$$W_2 = \frac{2}{\pi}tan^{-1}(k\Delta t)$$

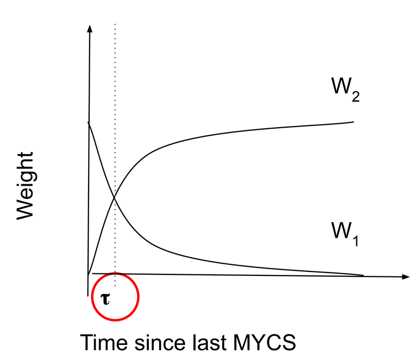


Figure 2: Graph showing W1 and W2 relationship with τ highlighted as the point their dominance shifts.

The stability score balances the short term, long term, and quality of the station at the last Multi Year CORS Solution (MYSC). RMS1 is the RMS value at the time of the MYCS, RMS 2 is calculated from the daily residuals from the day of interest to MYCS (long term) and RMS3 only uses the last 28 days (short term), these are shown in FIgure 3. To balance these three components a two tiered weighing scheme was developed. Figure 2 shows the relationship of the second weighting structure.

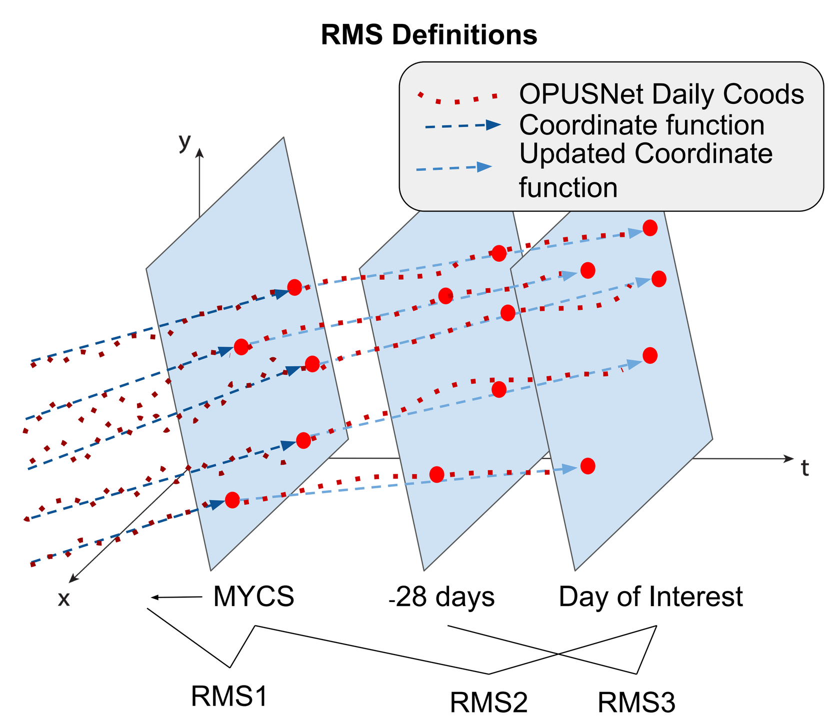


Figure 3: Schematic explaining RMS definitions

4. Refining the Parameters

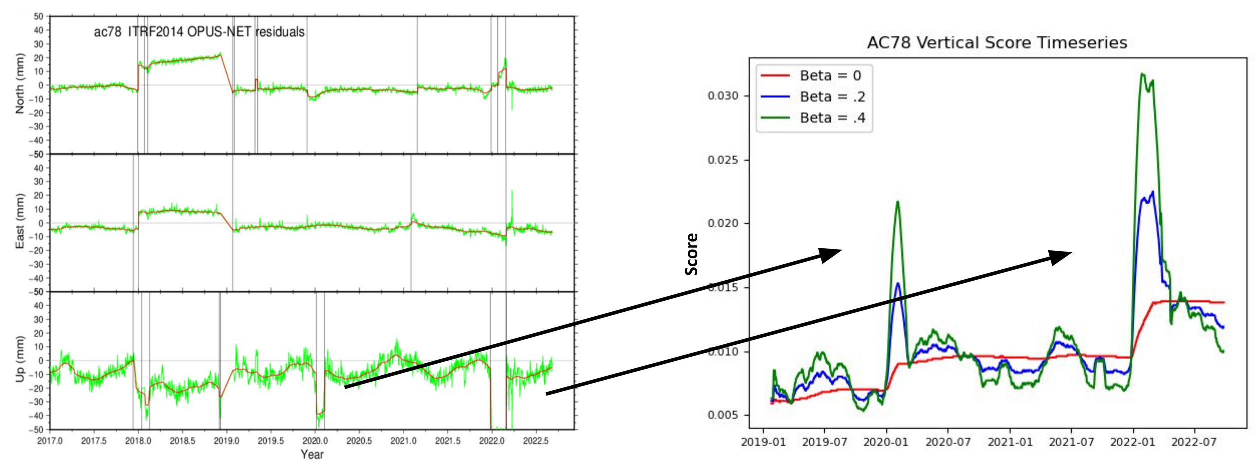


Figure 4: Left, OPUS-Net residuals for station AC78 used to monitor the CORS network. Right, AC78 vertical score timeseries with different beta values.

Different alpha and beta weights were tested. This was important in determining how much to weight the short term. In Figure 4, we see that when **β** = .4 the score is too responsive to the short term but when **β** = 0, meaning no short term the score doesn't capture the jumps shown in the residual timeseries on the left.

5. Results

Station Timeseries

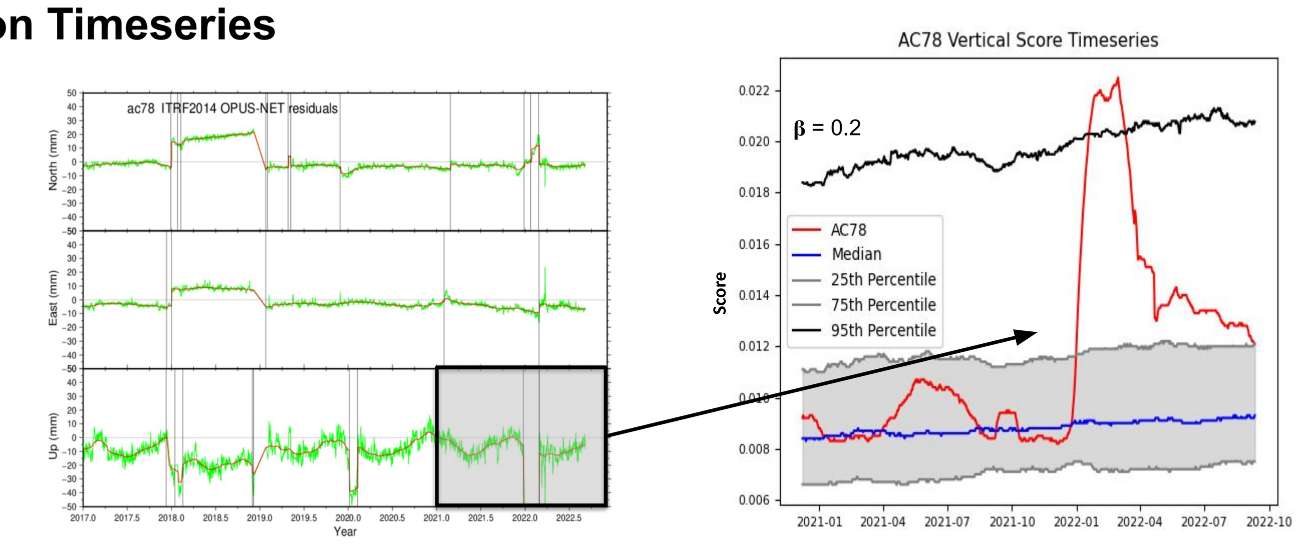


Figure 5: Left, OPUS-Net residuals for station AC78. Right, AC78 vertical score timeseries with the median timeseries of the entire network shown in blue.

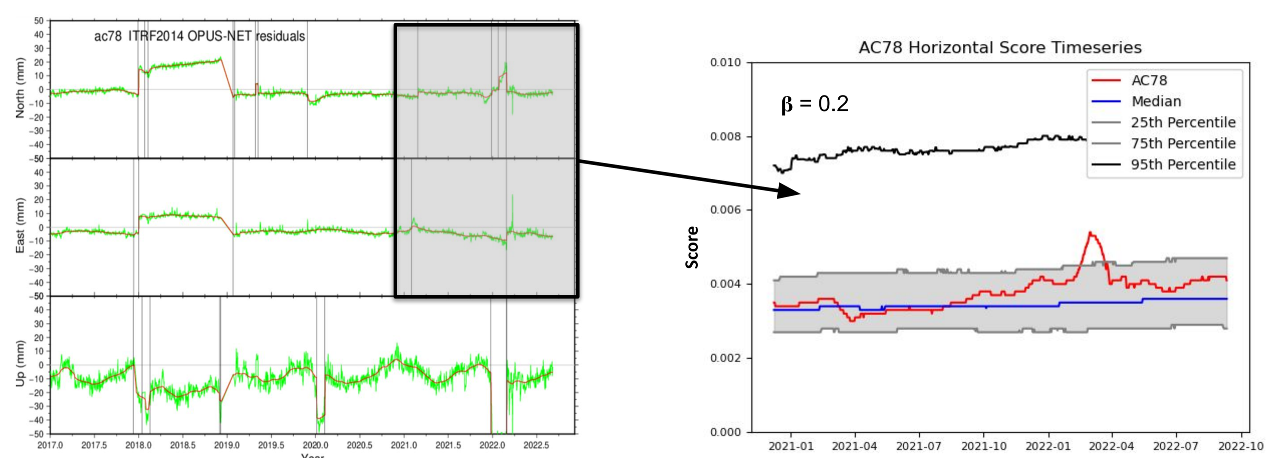


Figure 6: Left, OPUS-Net residuals plot for station AC78. Right, AC78 horizontal score timeseries with the median timeseries of the entire network shown in blue.

Figure 5 and 6 demonstrates that the scores are reacting as expected. AC78 falls between the 25th-75th percentile of network daily scores until the large motion highlighted in Figure 5, after a slight delay, the score shoots up shown on the right. In the horizontal components we see the same thing as we saw in the vertical. AC78 is within the 25th-75th range until their is motion in the north and east.

Daily Score Distribution

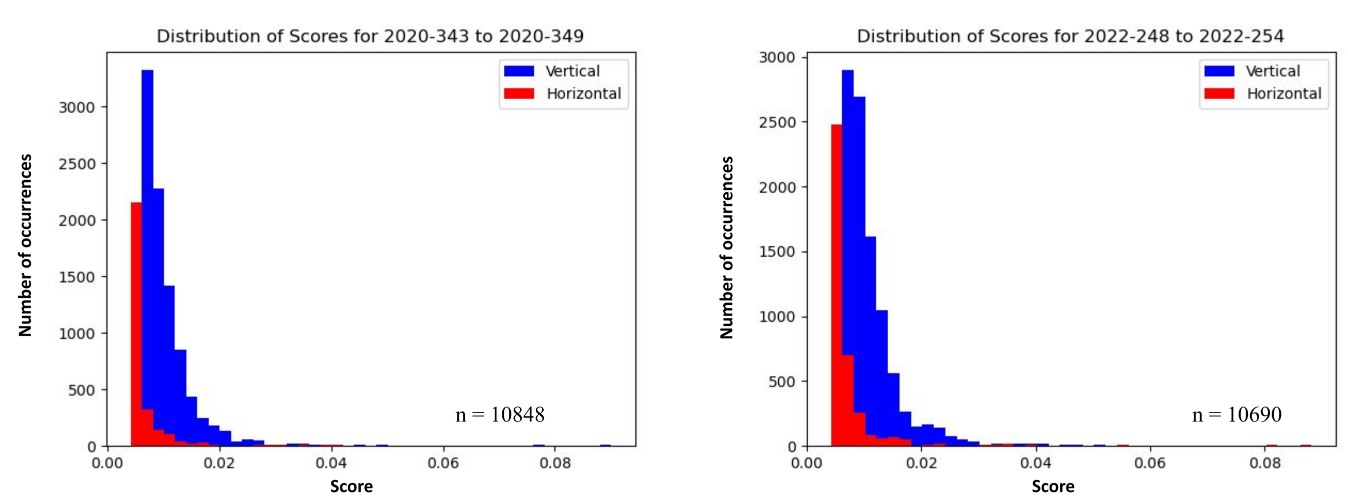
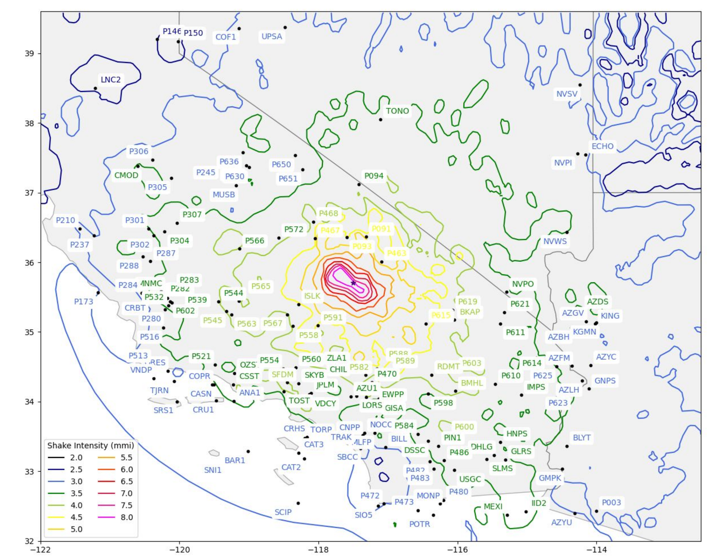


Figure 7: Vertical and horizontal score distribution over 2 different weeks.

We expect the scores to mostly all fall within a narrow range and then only a few stations to tail off with higher scores. This is confirmed by looking at Figure 7.

6. Additional Research Questions

How do station scores react after an earthquake?



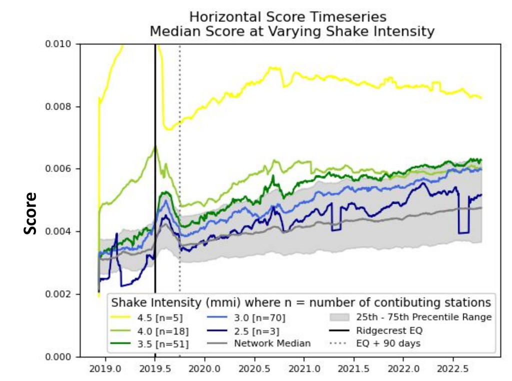


Figure 8: Left, Shake intensity contours from the Ridgecrest earthquake with CORS stations overlaid. Right, median score timeseries for the stations seen of the left in each contour.

In Figure 8 (left) we see the four different contours medians all react the same after the earthquake, resulting in relatively parallel lines. An important feature to note is the bump immediately following the earthquake which resolves itself after around 90 days. We suspect this bump is seen network wide due to the way we constrain the IGS stations in our network processing. We think this 90 day timeframe is seen because NGS corrected the coordinate functions within 60 days however, our algorithm includes a short term element that takes into account the last 28 days. We plan to investigate further. After around a year, the contour medians flatten out matching the slope of the overall network median.

How does the "unstable" west compare to the "stable" east?

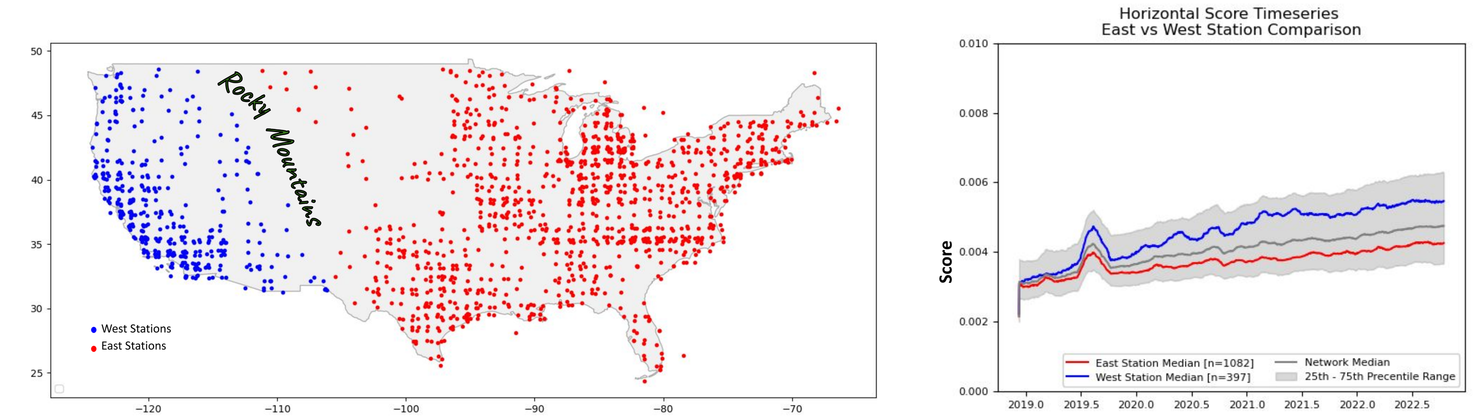


Figure 9: Left, CONUS map with CORS stations. Right, median score timeseries for west stations and the east stations shown on the map to the left.

In Figure 9, we see what is expected, that the west has higher scores than the east. However, we are surprised to see that the east still has the bump following the Ridgecrest earthquake.

Where is this bump coming from?

We are likely relying too heavily on too few stations when we realize the IGS frame. If GOL2 contributed heavily to our station solutions after Ridgecrest, it would make the network look worse than it is. This discovery has led to conversations at NGS about how we do our network monitoring.

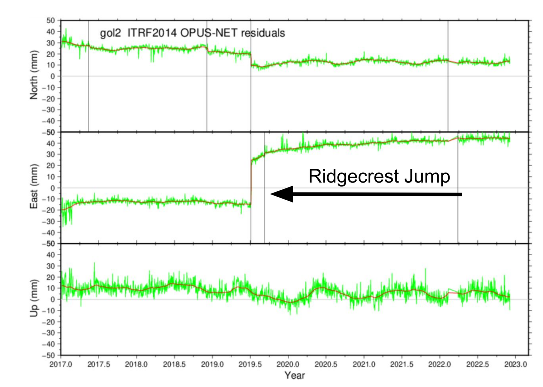


Figure 10: OPUS-Net residuals plot for station GOL2.

7. Future Work and Conclusions

- This work highlighted a weakness in NGS's processing strategy for network monitoring.
- Scores are acting as expected and can be used for to inform station selection. We are now working with the OPUS team to integrate this method
- We hope to display the score timeseries and daily score histograms on the CORS station pages so that users can access this information.

8. References

- USGS shake intensity USGS, "M 7.1 - 18km W of Searles Valley, CA Intensity Contours,"Last updated 2019-08-15, https://earthquake.usgs.gov/product/shakemap/ci38457511/atlas/1594160054783/download/cont_mmi.json