MARKET SURVEILLANCE COMMITTEE

Mosaic Design Performance and Conceptual Framework

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Introduction

The Department of Market Monitoring (DMM) recent report on the MOSAIC model, “Review of Mosaic quantile regression for estimating net load uncertainty,” provides many important insights into the design and performance of the CAISO’s mosaic model. [1]

- These slides focus on a few topics covered in the report that I believe require discussion.
- I have not fully absorbed all of the information in the report and will likely focus on other topics covered in the report in the future.

- 1. http://www.caiso.com/Documents/Review-of-the-Mosaic-Quantile-Regression-Nov-20-2023.pdf (DMM Mosaic Report)

Topics

- Mosaic Performance
- Potential Causes of Poor Performance
- Potential Resolutions

Mosaic Performance

Past ISO and DMM analysis has provided indications that the mosaic modeling approach is not performing as well as anticipated. DMM's recent review of the mosaic methodology provides several types of evidence that the mosaic methodology is not performing materially better than the prior histogram methodology, and may be performing worse.

I will only review a few of the metrics compiled by the DMM. I will focus on estimates of upward uncertainty in the 15 minute market.

Table 4.1 shows that over all hours the mosaic methodology reduces the uncertainty requirement by nearly 10% relative to the histogram method with a 1% reduction in coverage and a 3.2% increase in the megawatt amount by which actual uncertainty exceeds the requirement when the requirement is insufficient.[2]

Table 4.2, however, shows that over hours 17-21 the mosaic methodology reduces the uncertainty requirement by only 2% relative to the histogram method with a 1% reduction in coverage and a 13% increase in the amount by which actual uncertainty exceeds the requirement when the requirement is insufficient. [2]

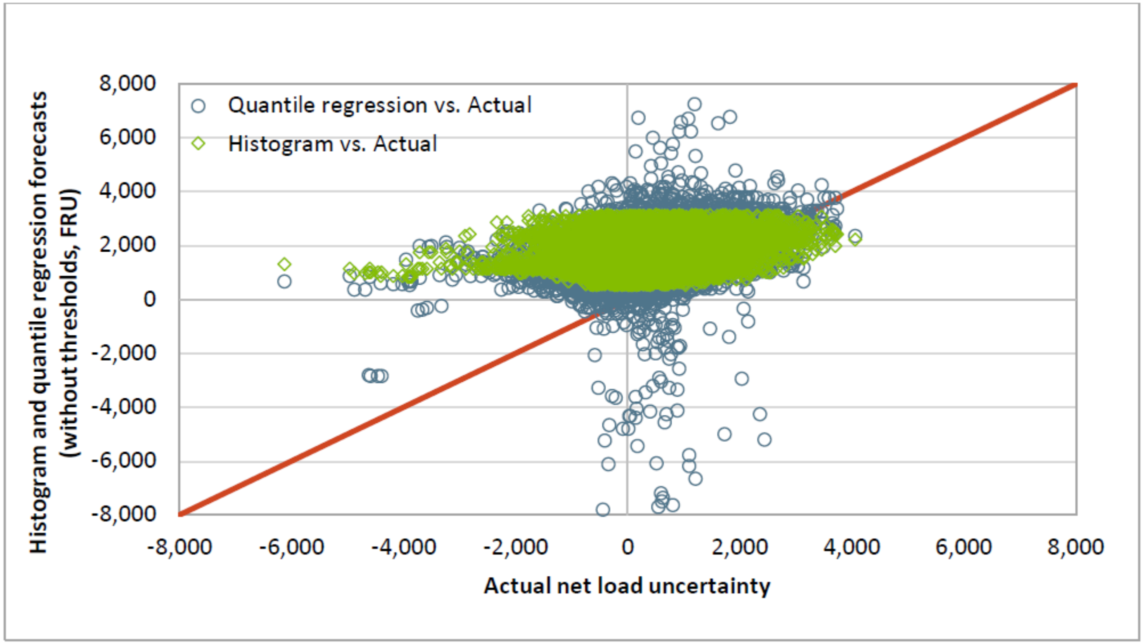
DMM carried out these calculations using the same sample for the histogram and the mosaic estimates so the poor performance is not due to differences in sample size. [2]

1. California ISO, Department of Market Monitoring, Review of mosaic quantile regression for estimating net load uncertainty, November 20, 2023. pp. 11,12 (Mosaic Report).

Mosaic Performance

Figure 4.4 in the DMM report shows that even this relatively poor level of mosaic model performance was significantly dependent on the application of ad hoc thresholds to screen out wildly anomalous requirements. [1]

Figure 4.4 Flexible ramping up coverage of histogram and mosaic quantile regression forecast (no thresholds, February-September 2023)

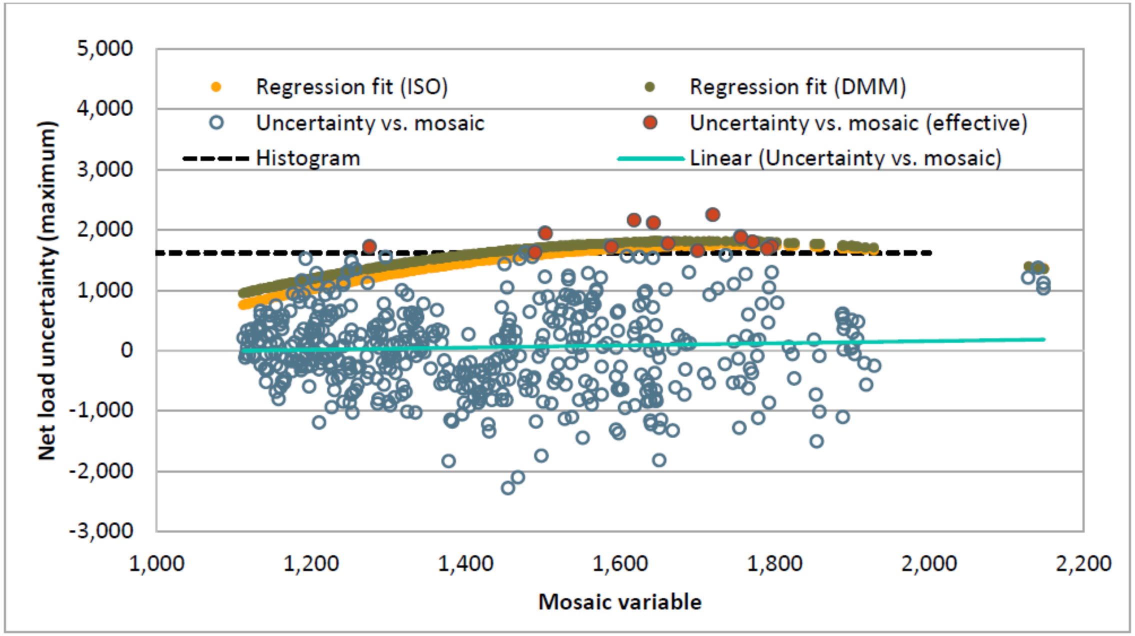


Source: California ISO, Department of Market Monitoring, Review of mosaic quantile regression for estimating net load uncertainty, November 20, 2023. p. 16

Mosaic Performance

The DMM analysis also suggests that in some months and hours there is no apparent relationship in the historic data between the mosaic variable and actual forecast error.

Figure 5.11 Mosaic quantile regression fit for upward pass-group uncertainty (hour-ending 13, March 1, 2023)



Source: California ISO, Department of Market Monitoring, Review of mosaic quantile regression for estimating net load uncertainty, November 20, 2023. p. 31, see also Figure 5.13 on page 33.

Mosaic Performance

The performance of the mosaic methodology as measured by DMM is disappointing. There is a reasonable expectation that conditioning the uncertainty forecasts for wind and solar output on the forecast output would yield better estimates than the histogram methodology.

- A regression methodology conditioned on forecasts should generate lower estimates of downward output uncertainty when forecasted wind and solar output are low and higher estimates of downward output uncertainty when forecasted wind and solar output are higher.
- There are a number of indications in the DMM analysis that the regression methodology is sometimes producing uncertainty forecasts that are related to the level of the mosaic variable. [1] However, the DMM analyses indicate that the mosaic methodology is nevertheless not producing much, if any, improvement in predicting uncertainty relative to an unconditioned histogram methodology based on the same sample.

1. See, for example, DMM Mosaic Report figures 5.9, 5.14, 5.15, 5.16. However, as discussed below this apparent relationship may be a spurious result of a mis-defined sample period.

Causes

There are a variety of potential reasons for this poor performance that need to be considered. Some reasons include:

- The gains from conditioning the uncertainty forecast on forecast wind and solar output are low because in most hours the forecasted output is similar, so the gains only impact a small portion of the hours.
- There are material gains at the balancing area level of conditioning the estimate of uncertainty on forecasts, but the gains are not material/smaller at the pass group level. This could be the case if there is less variation in forecast wind and solar output at the pass group level than at the balancing area level.
- Flaws in the mosaic methodology are preventing the ISO from achieving the potential for improved forecast output conditioned uncertainty estimates.

Causes

The DMM analysis identifies a number of potential flaws in the mosaic methodology.

- The mosaic methodology for combining uncertainty estimates across load, wind and solar lacks a sound basis and is potentially leading to worse then necessary estimates.
- Inconsistencies relating to the varying composition of the pass group are leading to anomalous estimates.
- Seasonality: The 180 day look-back period extending back into months in a different season, with different sunset times, is likely leading to spurious estimates of the relationship between load, wind, and solar forecasts and expected uncertainty.

Causes: Mosaic Methodology

The ISO approach of separately estimating the uncertainty associated with the wind, solar and load forecast is reasonable. However, it requires a method for combining those estimates into a single value for net load uncertainty.

- The MOSAIC regression is apparently intended to be a way to combine the separate uncertainty estimates but a rationale for why combining histogram and quantile regression estimates is expected to yield good estimates is missing.

Mosaic Uncertainty$_t$ = Histogram Uncertainty + (Quantile Load Uncertainty$_t$- Histogram Load Uncertainty) + (Quantile Solar Uncertainty$_t$ – Histogram olar Uncertainty) + (Quantile Wind Uncertainty$_t$ – Histogram Wind Uncertainty)

Uncertainty$_t$ = Constant + b Mosaic Uncertainty$_t$ + a Mosaic Uncertainty$_t^2$

Causes: Mosaic Methodology

DMM points out that the mosaic methodology does not actually condition the estimates on the histogram values, the histogram values simply add what is effectively another constant term.

This additional constant term has no impact on the estimated impact of the Quantile regression variables on net load forecast error. [1]

1. DMM Mosaic Report pp. 47-49

Causes: Mosaic Methodology

The mosaic methodology effectively adds the estimated 2.5% uncertainties for load, solar output and wind output.

- This implicitly assumes that the uncertainties are perfectly correlated.
- This methodology will tend to produce mosaic values that are too high when there are multiple sources of material uncertainty. This is because the 2.5% confidence interval for the sum of three imperfectly correlated random variables will be less than the sum of their 2.5% confidence interval.
- This flaw in the mosaic methodology tends to reduce the potential benefits of conditioning the wind and solar uncertainties on the forecast, but detailed analysis would be required to determine how material the impact has been.
- This is the problem that I think the ISO was attempting to address with the mosaic design, a method for combining the separate estimates for load, solar and wind uncertainty. This is a fundamental issue with any design that conditions net load forecast uncertainty on forecasts of the individual components.

Causes: Pass Group Composition

DMM points out in its quarterly report that additional anomalies in estimated net load forecast error appear to arise from changing definitions of the pass group. [1]

- The DMM analysis indicates that about 10% of all hours have varying pass groups.
- This is a difficult issue to address within the framework of the current RSE and Mosaic design because of the limited time available to rerun models on multiple pass groups.
- It would be useful to breakdown tables 4.1, 4.2 and 5.2 between hours with a common pass group and varying pass groups to better understand the overall impact of this factor.

1. DMM Mosaic Report, Figure 139, p. 52.

Causes: Seasonality

The current ISO methodology looks back 180 days, which will include many days from a prior season, as well as days with a materially different sunset hour.

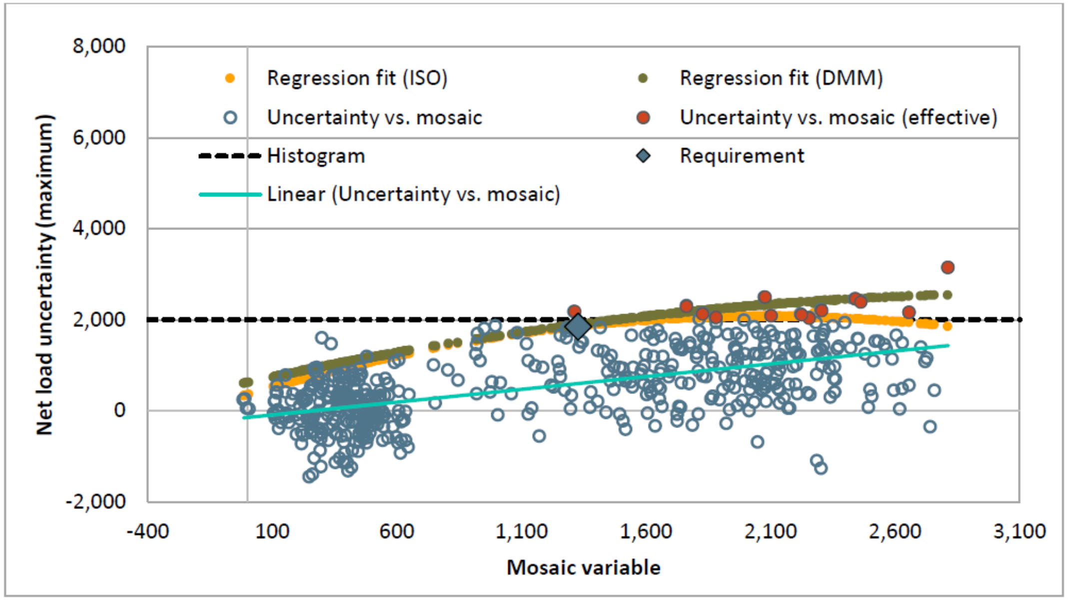
- For example, the data used to estimate the model for hour 19 June 15 will include data back to December 15, at which time there is no solar output in hour ending 19.
- DMM's Figure 5.16 shows many data points with very low mosaic values. These are are likely winter months with no solar output in hour ending 19.[1]

1. DMM Mosaic Report, Figure 5.16 p.35.

Causes: Seasonality

Figure 5.16 shows the data for the mosaic regression for hour 19, June 15, 2023. Notice that the mosaic variables are clustered in the range between 100 and 600 and there are only a small number of data points above 2200

Figure 5.16 Mosaic quantile regression fit for upward pass-group uncertainty (hour-ending 19, June 15, 2023)

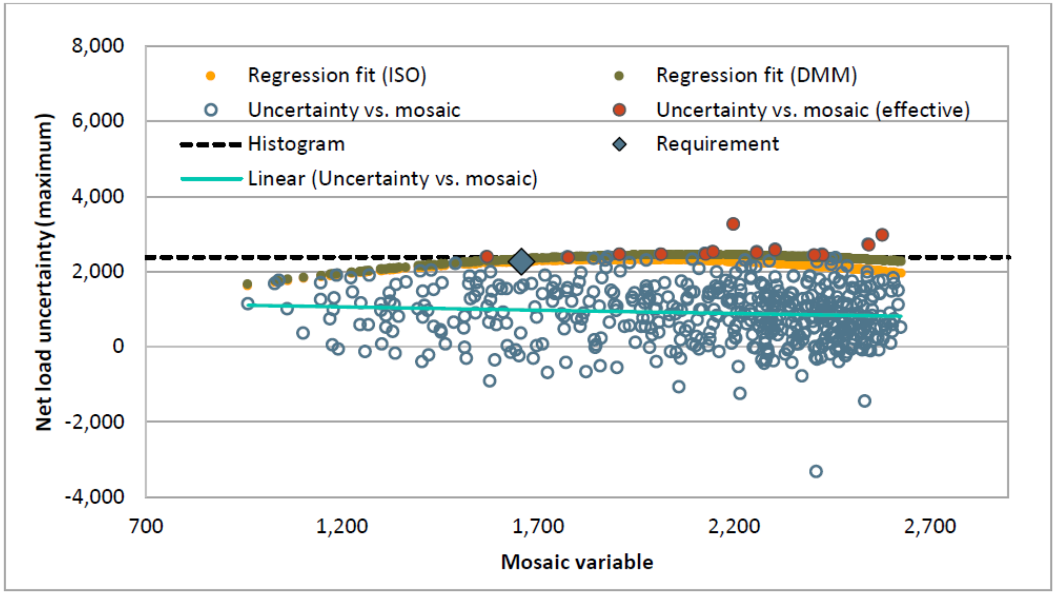


Source: California ISO, Department of Market Monitoring, Review of mosaic quantile regression for estimating net load uncertainty, November 20, 2023, p.35

Causes: Seasonality

Figure 5.19 shows the data for the mosaic regression for hour 19, September 15, 2023. Note that the mosaic variable values are clustered in the range above 2200 and there are no values below around 900

Figure 5.19 Mosaic quantile regression fit for upward pass-group uncertainty (hour-ending 19, September 15, 2023)



Source: California ISO, Department of Market Monitoring, Review of mosaic quantile regression for estimating net load uncertainty, November 20, 2023. p. 37.

Causes: Seasonality

A comparison of figures 5.16 and 5.19 suggests that all of the low data points in Figure 5.16 were from the December 15 to March 15 period, with low solar output in hour 19, data points which drop out of the September data in Figure 5.19.

These graphics suggest that the long look back period is not adding much useful information and may lead to a spurious relationship between forecast output and net load uncertainty that actually reflects seasonal differences.

Mosaic Statistical Model

DMM has found that there are only a few hours over the day in which the estimated linear coefficient ”b” for pass group upward uncertainty is typically statistically significantly different from zero based on their bootstrapping analysis. [1]

- The frequency of estimates of the non-linear coefficient “a” being statistically significantly different from zero is generally even lower.
- The coefficient “b” describing the linear relationship between the mosaic variable in uncertainty is statistically significantly different from zero in less than 20% of the days in 11 out of 24 hours, and is statistically different from zero in more than 50% of the days in only two hours.
- The DMM analysis shows that the statistical significance of the mosaic variables is on average lower than for the wind, load and solar models. For example, coefficient “b” is estimated to be statistically significantly different from zero 23% of the time in the mosaic regressions, 67% in the solar regressions, 36% of the time in the wind regressions and 31% of the time in the load regressions.

1. DMM Mosaic Report Table 5.2 p. 40. The DMM assessment of statistical significance is based on a bootstrapping methodology. This is a reasonable approach but I have not reviewed the details of the DMM analysis.

Mosaic Statistical Model

It is noteworthy that not only are the estimates of the coefficients for the mosaic variables typically not statistically different from zero, but the coefficients for the relationship between wind output forecast and wind uncertainty and the load forecast and load forecast uncertainty are also often not statistically different from zero.

- The coefficient for the linear relationship between the wind output forecast and wind output uncertainty is statistically significantly different from zero in less than 20% of the days in 7 out of 24 hours, and is statistically different from zero in more than 50% of the days in only four hours.
- The coefficient for the linear relationship between the load forecast and load uncertainty is statistically significantly different from zero in less than 20% of the days in 7 out of 24 hours, and is statistically different from zero in more than 50% of the days in only two hours.

1. DMM Mosaic Report Table 5.2 p. 40 .

Mosaic Statistical Model

Moreover, while the linear coefficients of the solar forecast are statistically different from zero in over 85 percent of the days in 8 hours, this may simply reflect the fact that the look back periods includes different sunrise and sunset times and these variables may simply control for days in which the sun was not up in the sample period but was up in that hour in the study day and vice versa for days in which the sun was up in the sample period but not up in the hour on the study day. [1]

- This is a general issue with the model: does the model predict day-to-day variations in net load uncertainty associated with changing wind and solar output forecast levels or is the model simply capturing differences in net load uncertainty and wind and solar forecasts from season to season?
- It might be informative to revisit Figures 5.15 through 5.19 in the DMM Mosaic Report portraying days in the same season in red, days in the prior season in blue and days from 2 seasons back in green, to better visualize what is driving differences in the mosaic variable.

1. DMM Mosaic Report Table 5.2 p. 40 .

Mosaic Statistical Model

These issues with the meaningfulness of the coefficient estimates for wind, solar and load forecasts go to the validity of the entire approach of conditioning estimated uncertainty on forecast levels. Questions the CAISO needs to answer include:

- To what extent is the poor predictive power of the model due to sample periods that look back into completely different seasons and sunset and sunrise times?
- To what extent is the lack of significance associated with weekend hours and a small sample?
- To what extent is the lack of significance due to coefficient estimates that are close to zero (such as wind and solar coefficients less than .05 per thousand MW forecast) or to large estimated standard errors?

Mosaic Issues

1. Is there a same season relationship between forecast wind and solar output and forecast uncertainty at the pass group level?
2. Look back period seasonality
3. Solution time impact of mosaic methodology
4. How to combine estimates of load, wind and solar uncertainty into an estimate of net load uncertainty
5. Varying RSE pass groups from test to test
6. Weekend sample size (also weekday sample size if the sample period is changed)

Histogram Issues

1. Is there an in season relationship between forecast wind and solar output and forecast uncertainty at the pass group level, and if it is significant, how to account for it?
2. Look back period seasonality
3. Weekend sample size (also weekday sample size if the sample period is changed)

Potential Resolutions

There are a number of possible directions the CAISO could take:

- Address limitations of the mosaic model design – Several issues to address
- Return to a histogram methodology – But a histogram method would not yield much, if any, improvement
- Revisit both the mosaic and histogram methodologies with a different approach to seasonality and sample definition - May still not produce satisfactory results
- Use a lagged value of actual uncertainty – May not be workable for recent interval values
- Estimate variance of uncertainty based on normal distribution, perhaps adjust the estimated variance for heteroscedastic errors associated with the wind and solar forecast, and calculate 2.5% uncertainty targets – Shares some limitations of mosaic method, may be even more difficult to apply in real-time
- Estimate net load uncertainty as a linear function of the sum of forecast load, wind forecast and solar forecast – Uncertain predictive power and is only a partial solution
- Rethink RSE pass group design to avoid the need to estimate net load uncertainty for multiple pass groups in real-time – A big change

It may be desirable/necessary to take different approaches to estimating uncertainty for different purposes.