60802 Time Sync –
Monte Carlo Simulations with
RR & NRR Drift Tracking and Compensation –
Results Part 2

David McCall – Intel Corporation

Version 1

References

1 – David McCall "60802 Time Synchronisation – Monte Carlo Analysis: 100-hop Model, "Linear" Clock Drift, NRR Accumulation – Overview & Details, Including Equations – v2", contribution to IEC/IEEE 60802, September 2022

2 – David McCall "60802 Time Sync – Monte Carlo Simulations with RR & NRR Drift Tracking and Compensation –Initial Results – v2", contribution to IEC/IEEE 60802, July 2023

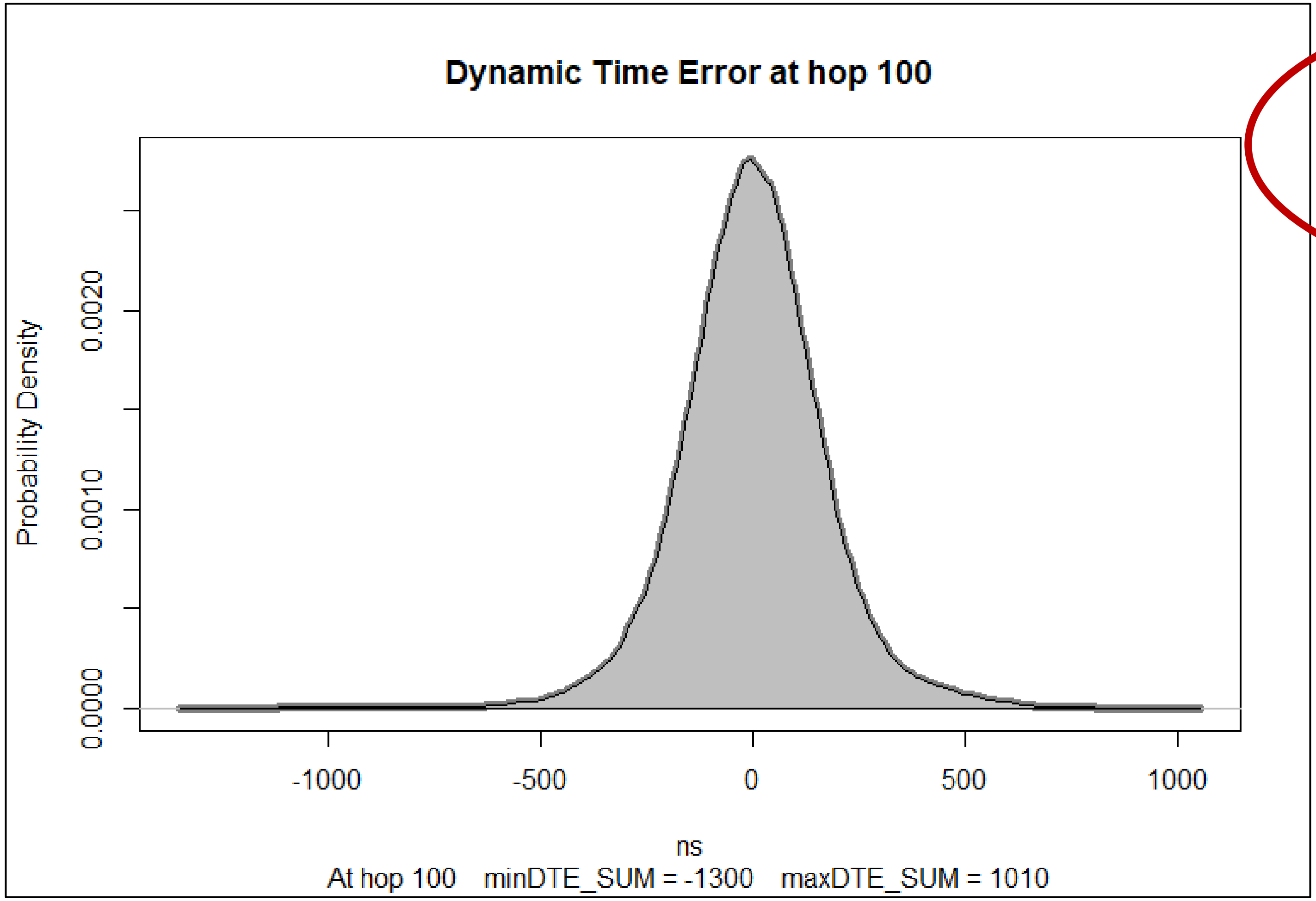
3 – David McCall & Kevin Stanton "60802 Dynamic Time Sync Error – Error Model & Monte Carlo Method Analysis", contribution to IEC/IEEE 60802, November 2021

Contents

- Initial Results, Hypotheses
- More Simulation Results – Questions & Answers
- Summary & Proposed Configuration for Time Series Simulations

Initial Results, Hypotheses and Questions

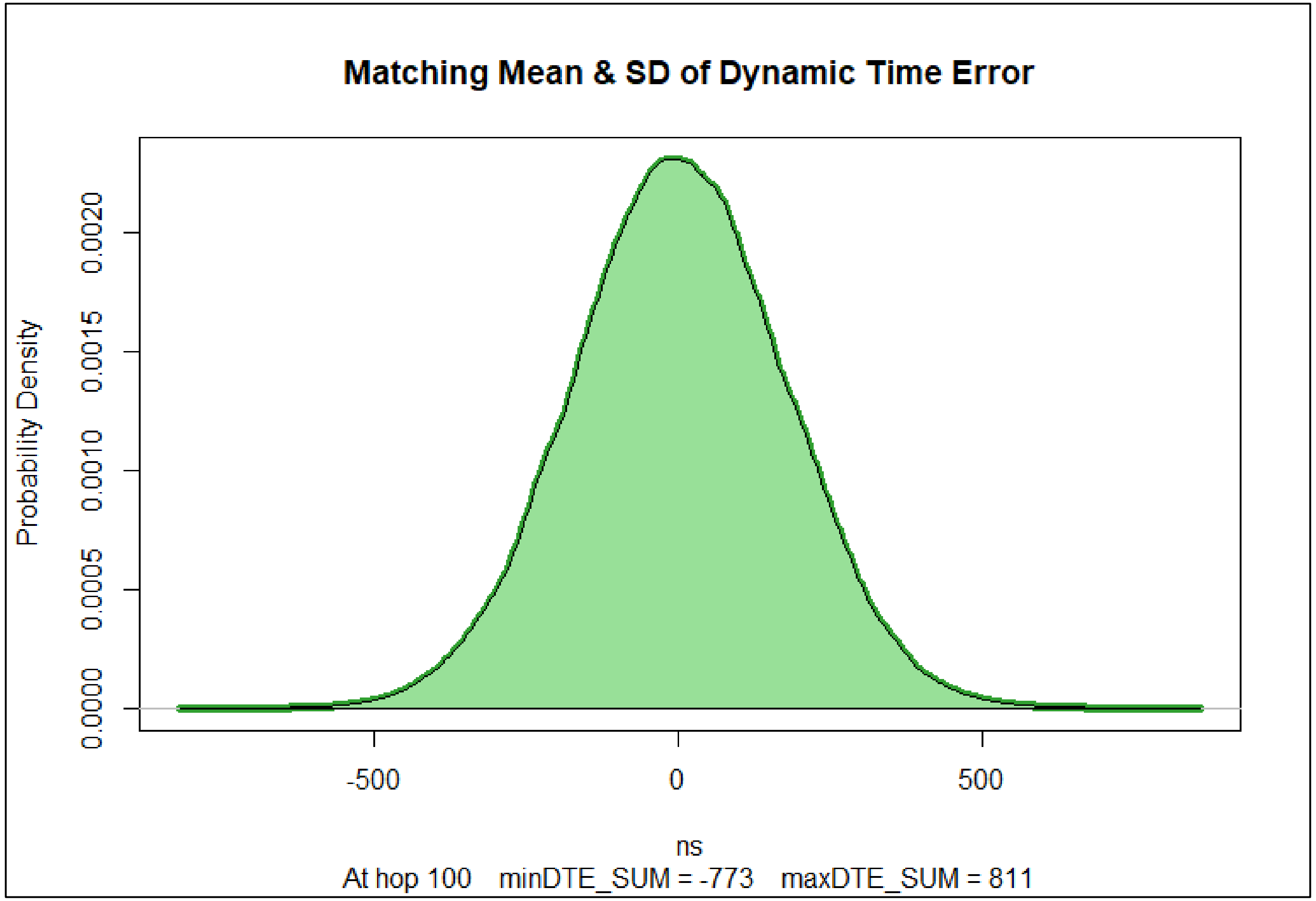
Default: Quarter-Sinusoidal; 125 s Temp Ramp; GM Scale 1



How true is this?

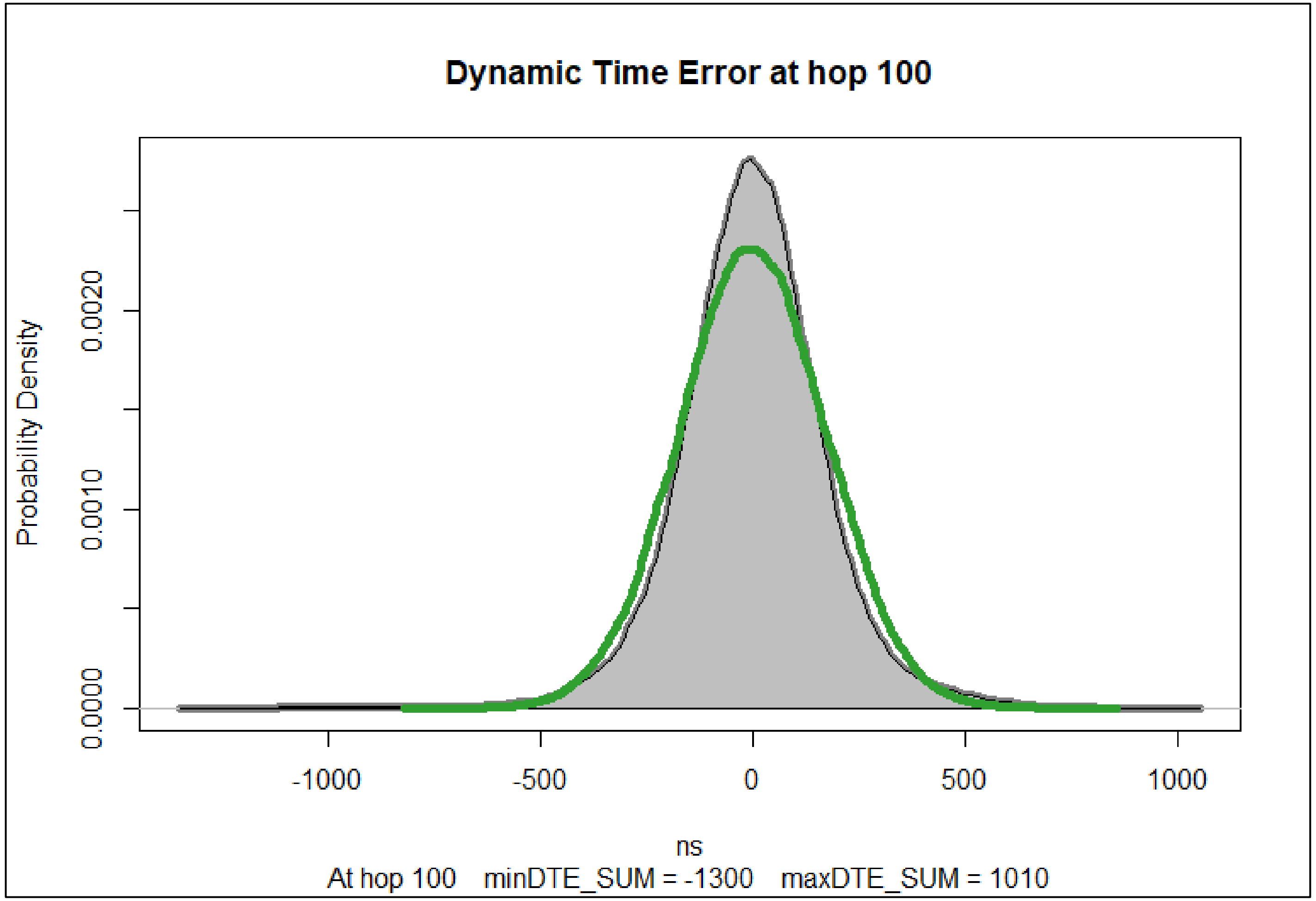
- Mostly a Normal distribution, but with extra-long tails
- Measured Mean: 0.33
- Measured σ: 171.58
- Min/Max -1300 to 1000 ns (approx.)
- 100,000 Runs

Normal distribution with matching mean and standard deviation



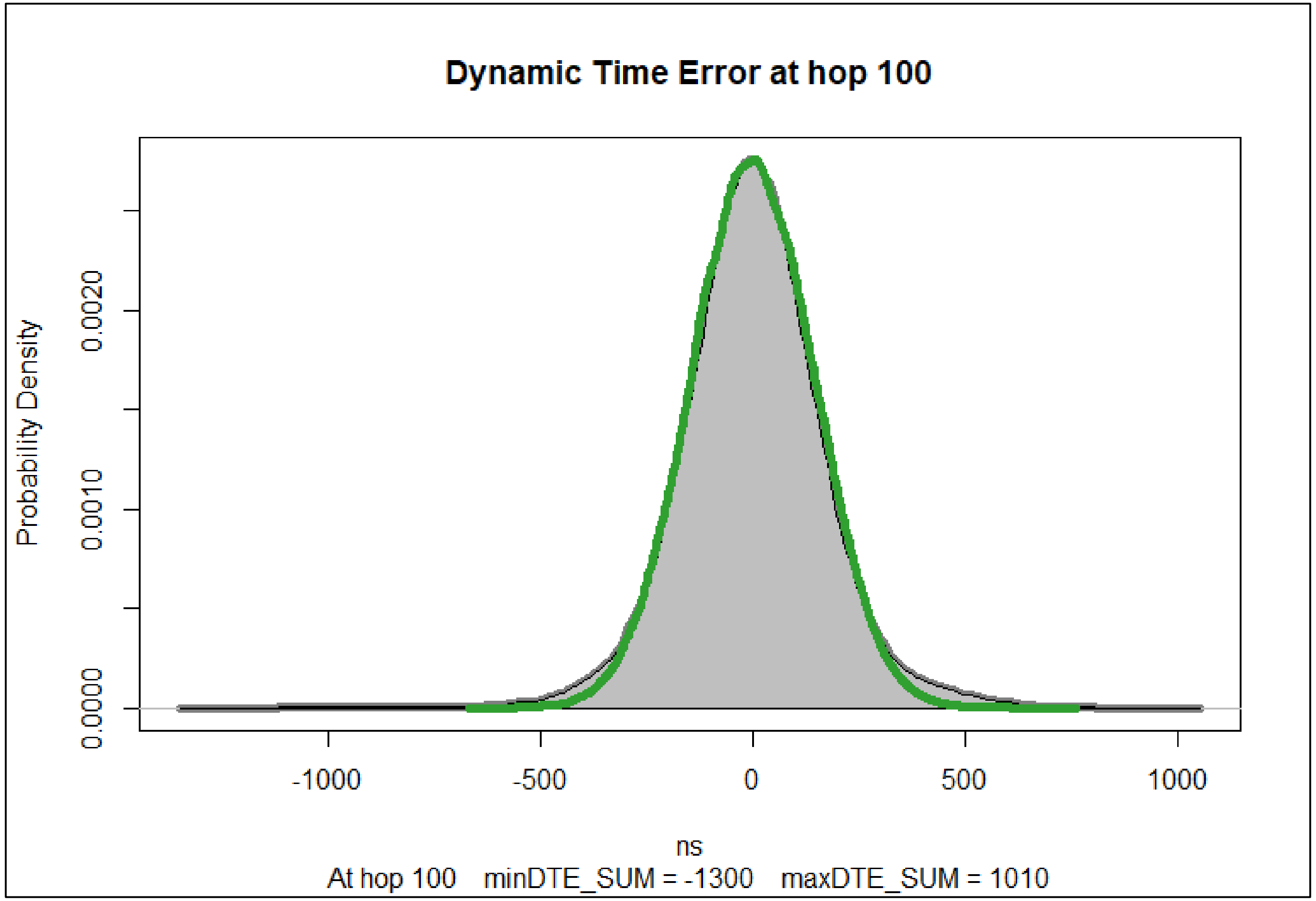
- Main part of bell-curve is slightly wider than DTE_SUM but with narrower tails
- Mean: 0.33
- σ: 171.58
- Min/Max ±870 ns (approx)
- 100,000 samples

Normal distribution with matching mean and standard deviation



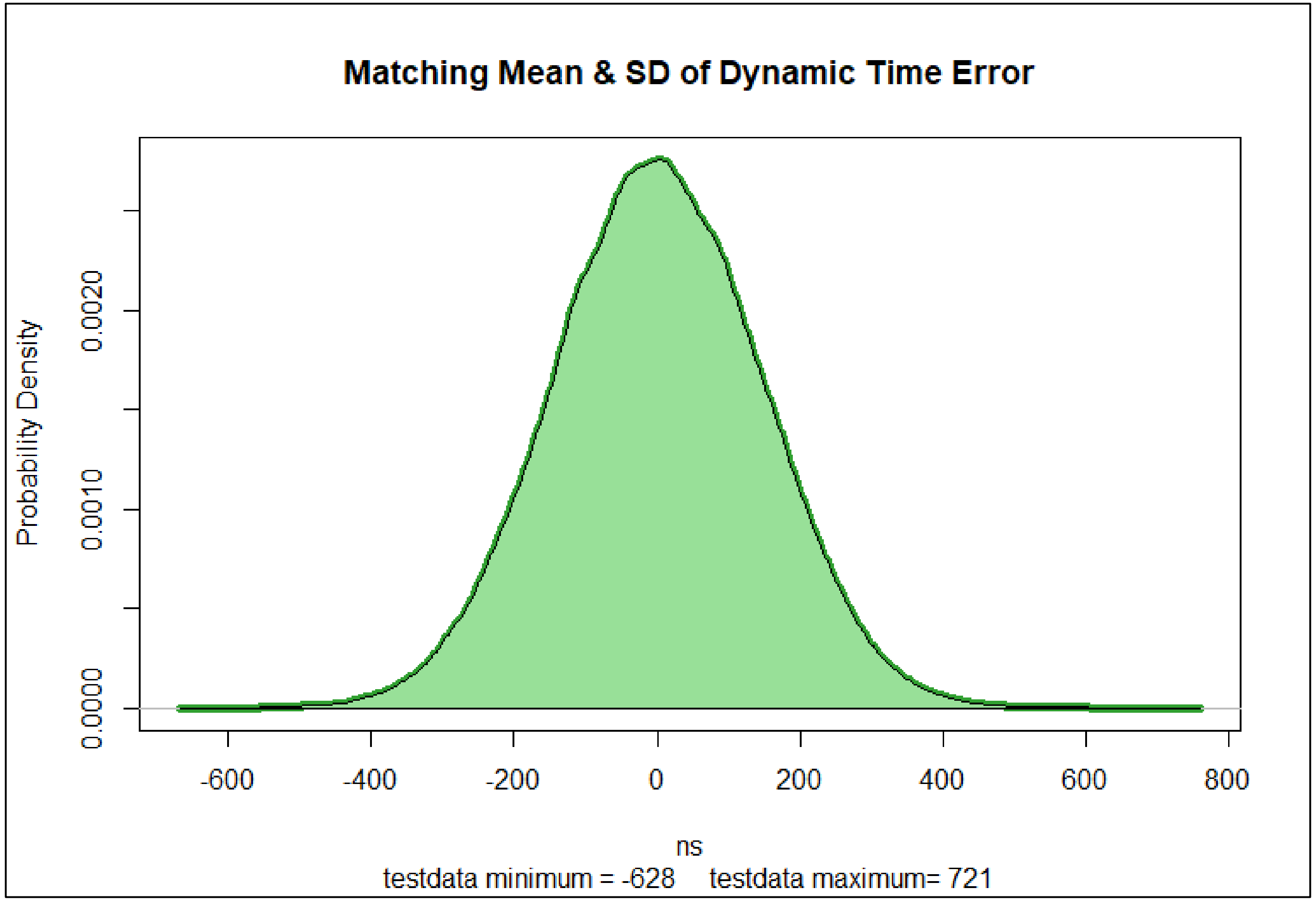
- Plotted on top of DTE_SUM.

Normal distribution to fit with main part of DTE_SUM bell curve



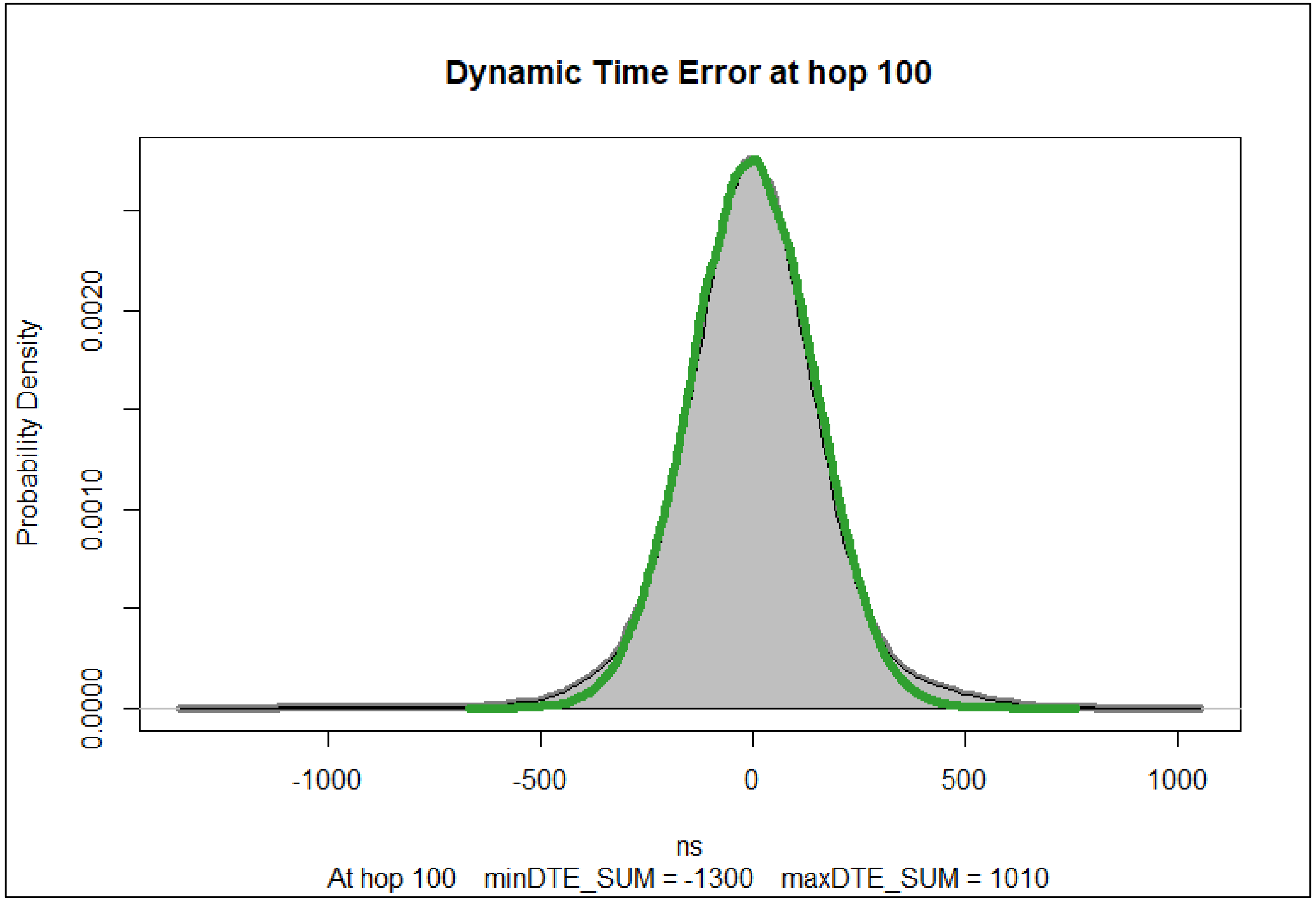
- Mean: 0.33
- σ: 144.5
- 100,000 samples

Normal distribution to fit with main part of DTE_SUM bell curve



- Mean: 0.33
- σ: 144.5
- Min/Max ±670 ns (approx)
- 100,000 samples

Default: Quarter-Sinusoidal; 125 s Temp Ramp; GM Scale 1



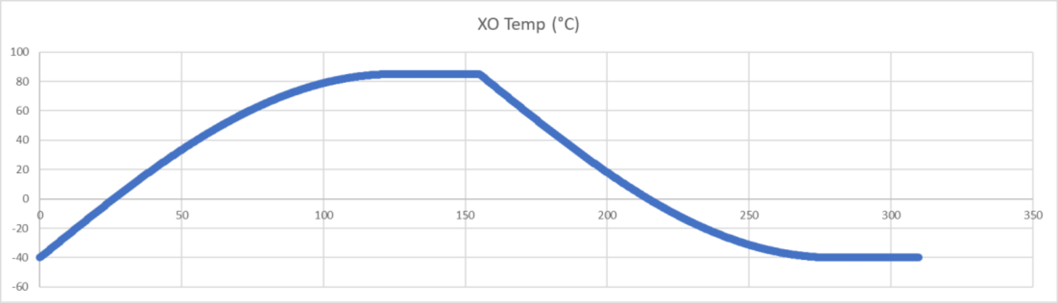
- **True**: mostly a Normal distribution, but with extra-long tails
- Specifically the main normal distribution would suggest Min/Max of ±670 ns rather than -1300 to +1000 ns (approx)

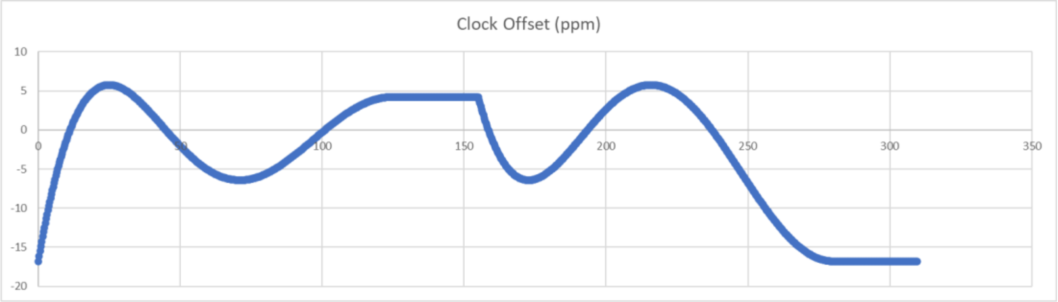
More Simulation Results – Questions & Answers

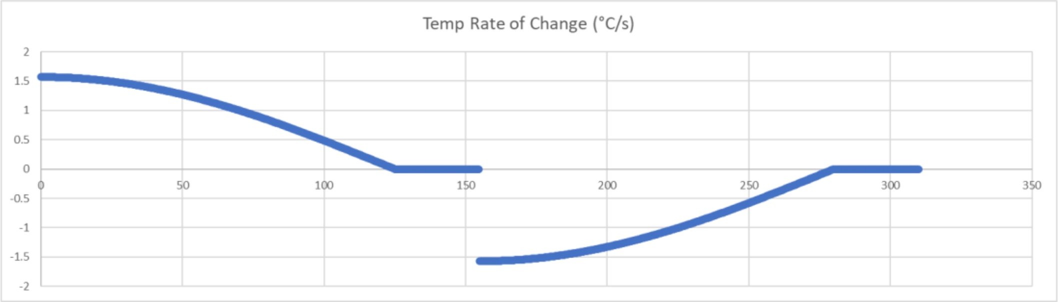
Hypothesis: ppm/s discontinuities are causing the "long tails"

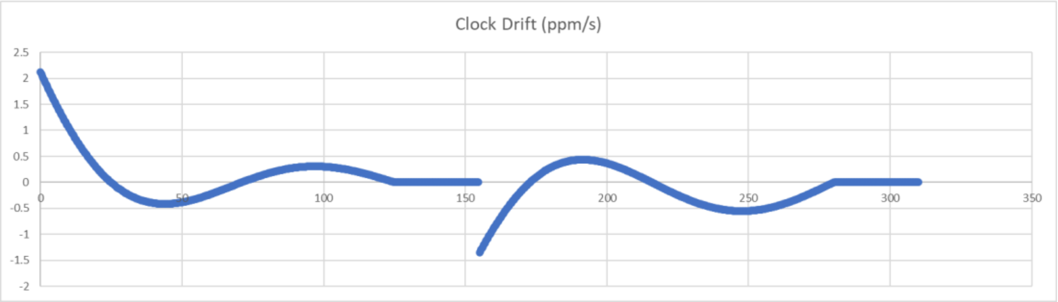
- The "Quarter Sinusoidal" temperature ramp includes two points which transition instantaneously from zero ppm/s to either maximum positive or negative ppm/s drift.
  - Clock Drift maximum: 2.12 ppm/s; minimum -1.35 ppm/s
- If the GM starts drifting immediately after sending a Sync message, the rest of the chain will be entirely unaware until the next Sync message.
  - Approx 500 ms for the Sync message to pass down the chain to the End Station, plus 125 ms until the next Sync message arrives at the End Station
- The tracking & compensation algorithms at Relay and End Station instances take up to 2 seconds to respond to changes in ppm/s.

Clock Drift Example –
Quarter-Sinusoidal Temperature Ramp: 125s ↕









Inputs		
Temp Max	85	°C
Temp Min	-40	°C
Temp Ramp Period	125	s
Temp Hold	30	s

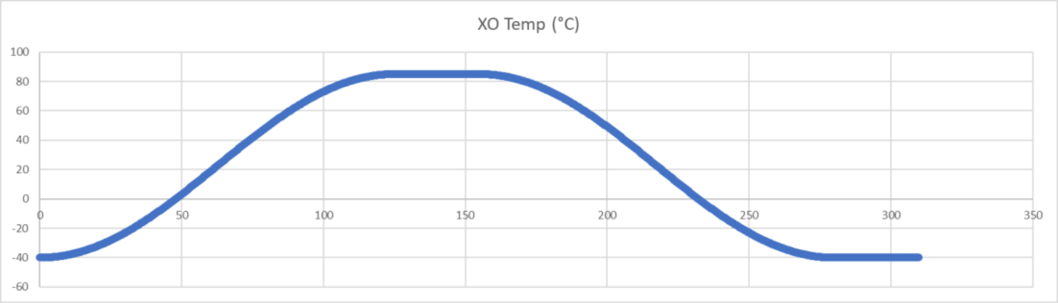
Temp Rate of Change		
MAX	1.57	°C/s
MIN	-1.57	°C/s

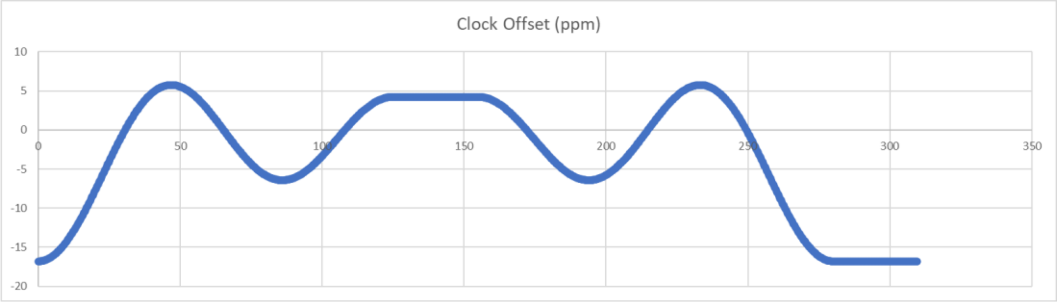
Clock Drift		
MAX	2.12	ppm/s
MIN	-1.35	ppm/s

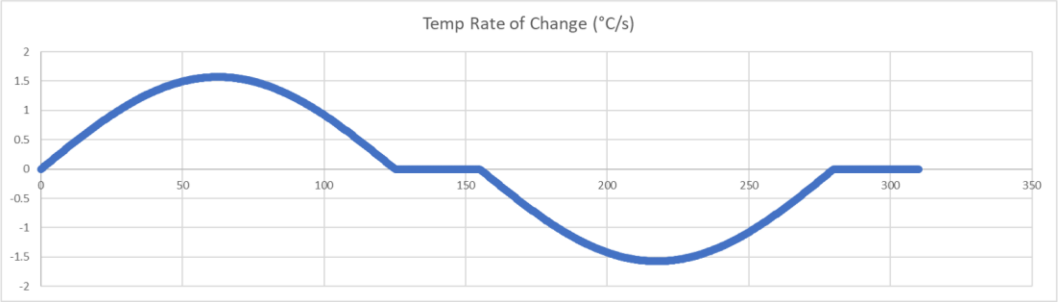
Hypothesis: a temperature curve without discontinuities will remove the long tails

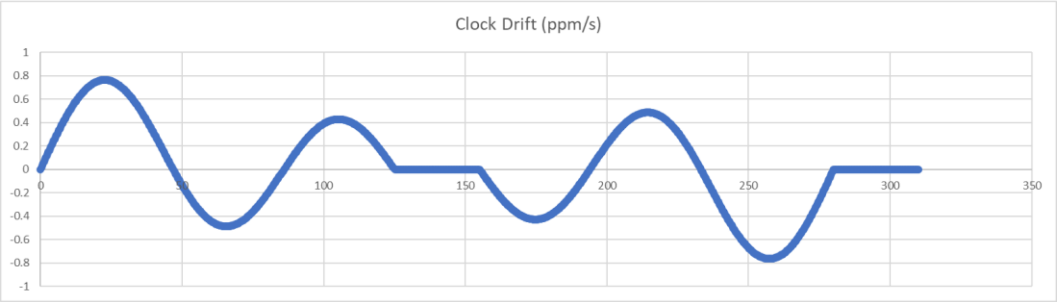
- The "Half Sinusoidal" temperature ramp starts and ends the ramp slowly
  - But, for same 125s ramp, Clock Drift maximum: 0.76 ppm/s; minimum -0.76 ppm/s.
  - May need to have faster ramp to match ±1 ppm/s normative requirement?

Clock Drift Example –
Half-Sinusoidal Temperature Ramp: 125s ↕







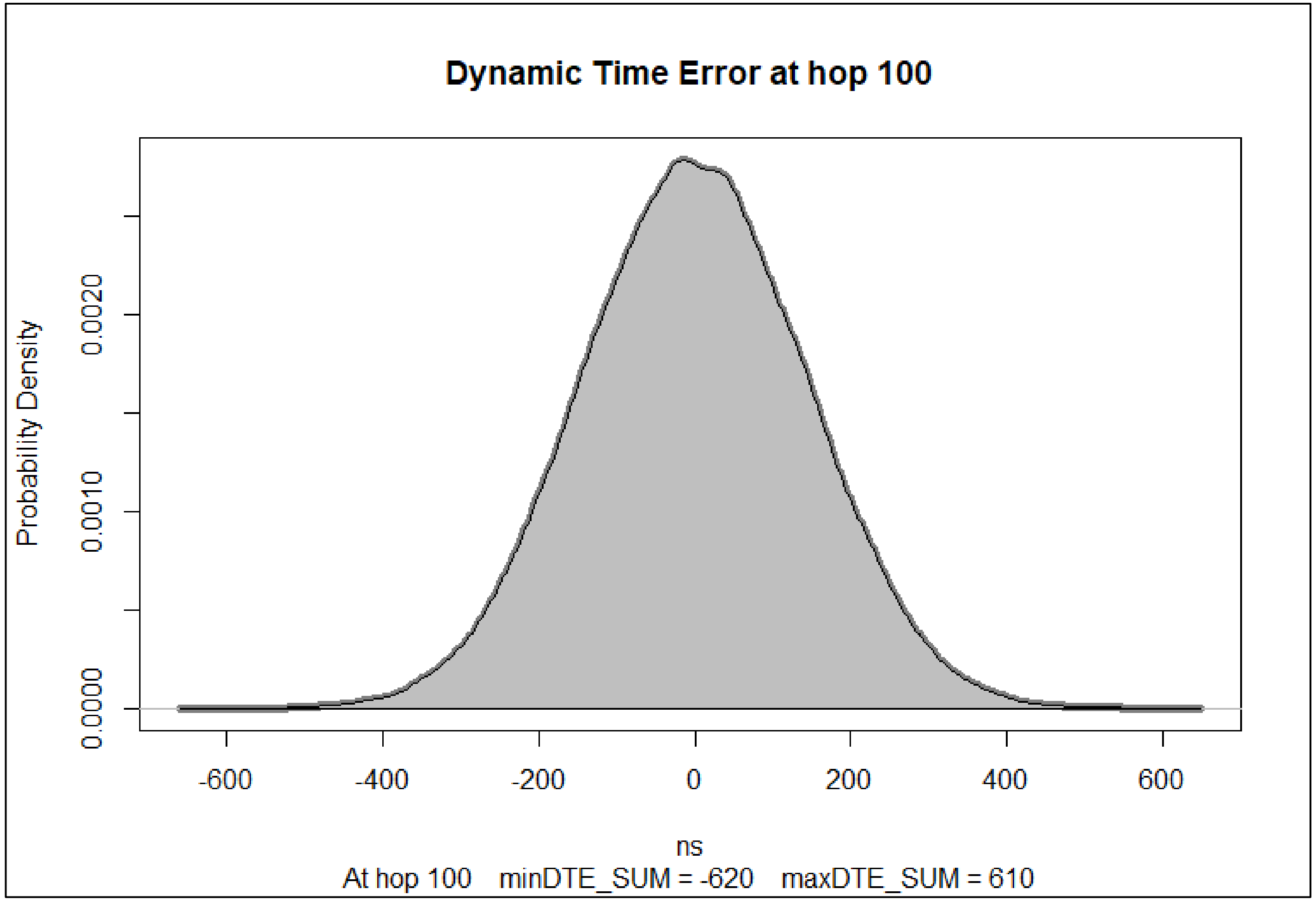


Inputs		
Temp Max	85	°C
Temp Min	-40	°C
Temp Ramp Period	125	s
Temp Hold	30	s

Temp Rate of Change		
MAX	1.57	°C/s
MIN	-1.57	°C/s

Clock Drift		
MAX	0.76	ppm/s
MIN	-0.76	ppm/s

Half-Sinusoidal; 125 s Temp Ramp; GM Scale 1

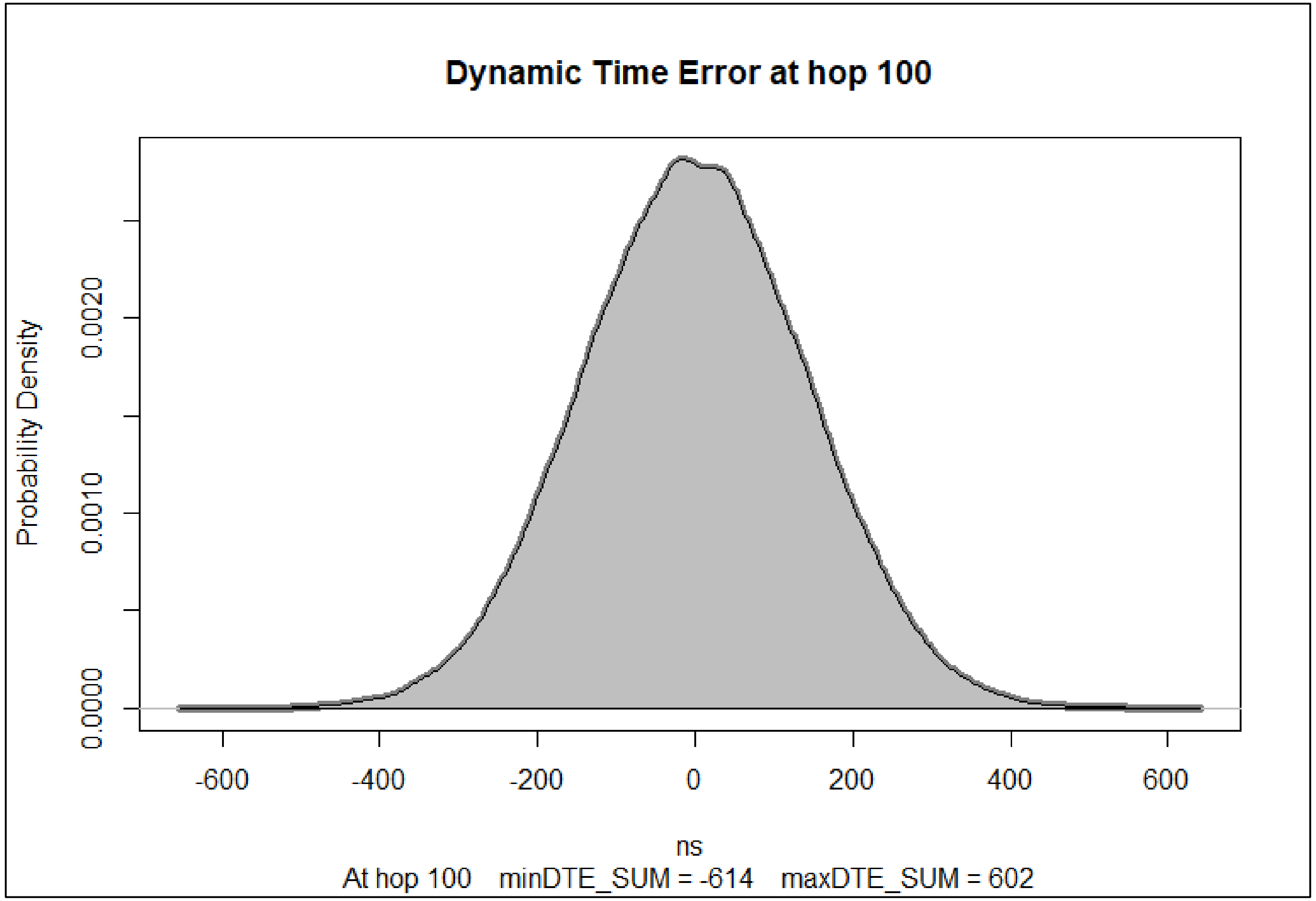


- Switching to Half-Sinusoidal Temp Ramp (no ppm/s discontinunities) minimises / removes the long tails.
- Min/Max ±615 ns (approx)

Hypothesis: using a GM with lower drift will further reduce time sync error

- GM clock drift has an outsized effect on time sync error
  - Consequent error doesn't tend to cancel out node-to-node as it does for errors due to clock drift at Relay instances
  - Resulting error in mRR survives and "pushes" time sync error off, in the same direction, down the entire chain of nodes, including the End Station.
- GMscale of 0.5 (equivalent of GM oscillator ±25ppm vs usual ±50ppm) results in simulation using half the error due to clock drift at the GM

Half-Sinusoidal, 125 s Temp Ramp, GMscale 0.5

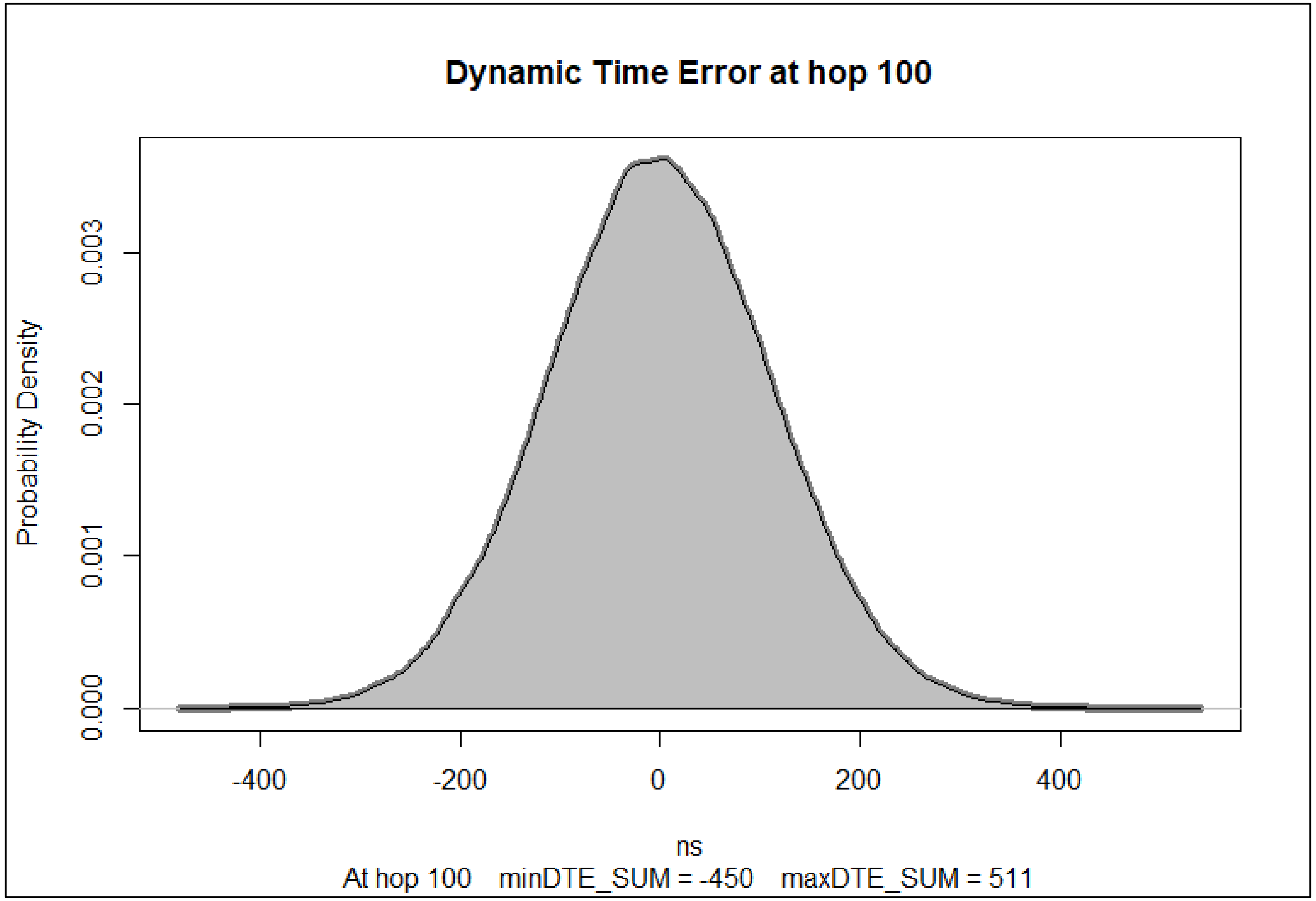


- Marginal improvement to Min/Max ±608 ns (approx)
- Clock Drift error from other nodes and other errors may be dominating?

Hypothesis: if the temperature ramp is less aggressive, time sync error will be further reduced

- Easiest way to do this is to increase the ramp time from 125s to, for example, 250s

Half-Sinusoidal, 250 s Temp Ramp GMscale 0.5



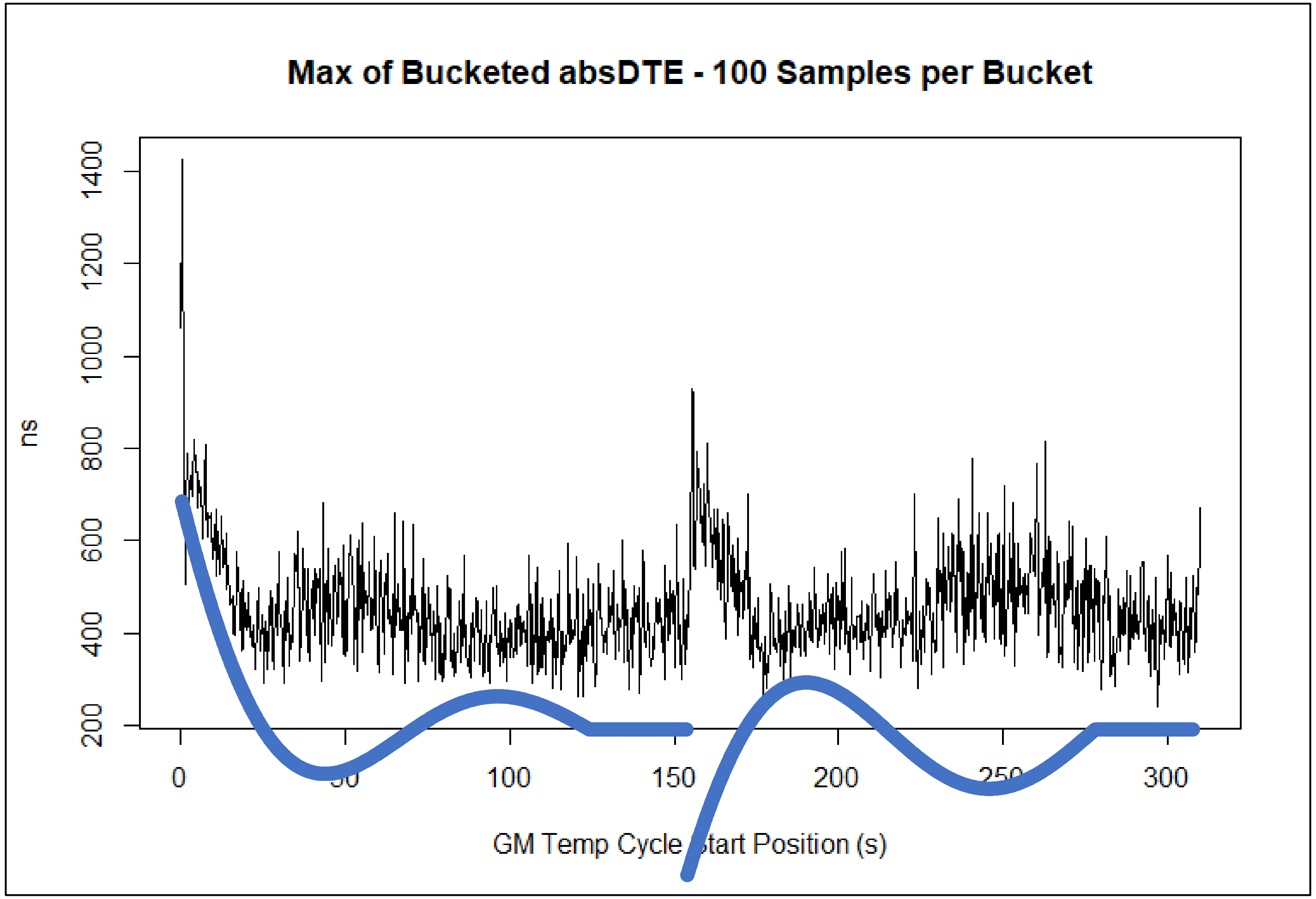
- Noticeable improvement!
- Min/Max ±480 ns (approx)
- But Min/Max ±0.38 ppm/s drift

More Results – Questions & Answers

Question: Are the long tails really due to the discontinuities?

- Investigate by…
  - Simulation where GM Temp Cycle start position is not random, but instead in sequence across Temp Cycle range, equally spaced
    - 100,000 runs across 310 s means, for each run, GM start point is incremented by 3.1 ms
  - Bucket absolute DTE_SUM results with each bucket containing 100 results
  - Find MAX value of dTE in each bucket
  - Plot MAX values over time
- Default values: Quarter-Sinusoidal; 125 s Temp Ramp; GM Scale 1

Question: Are the long tails really due to the discontinuities?

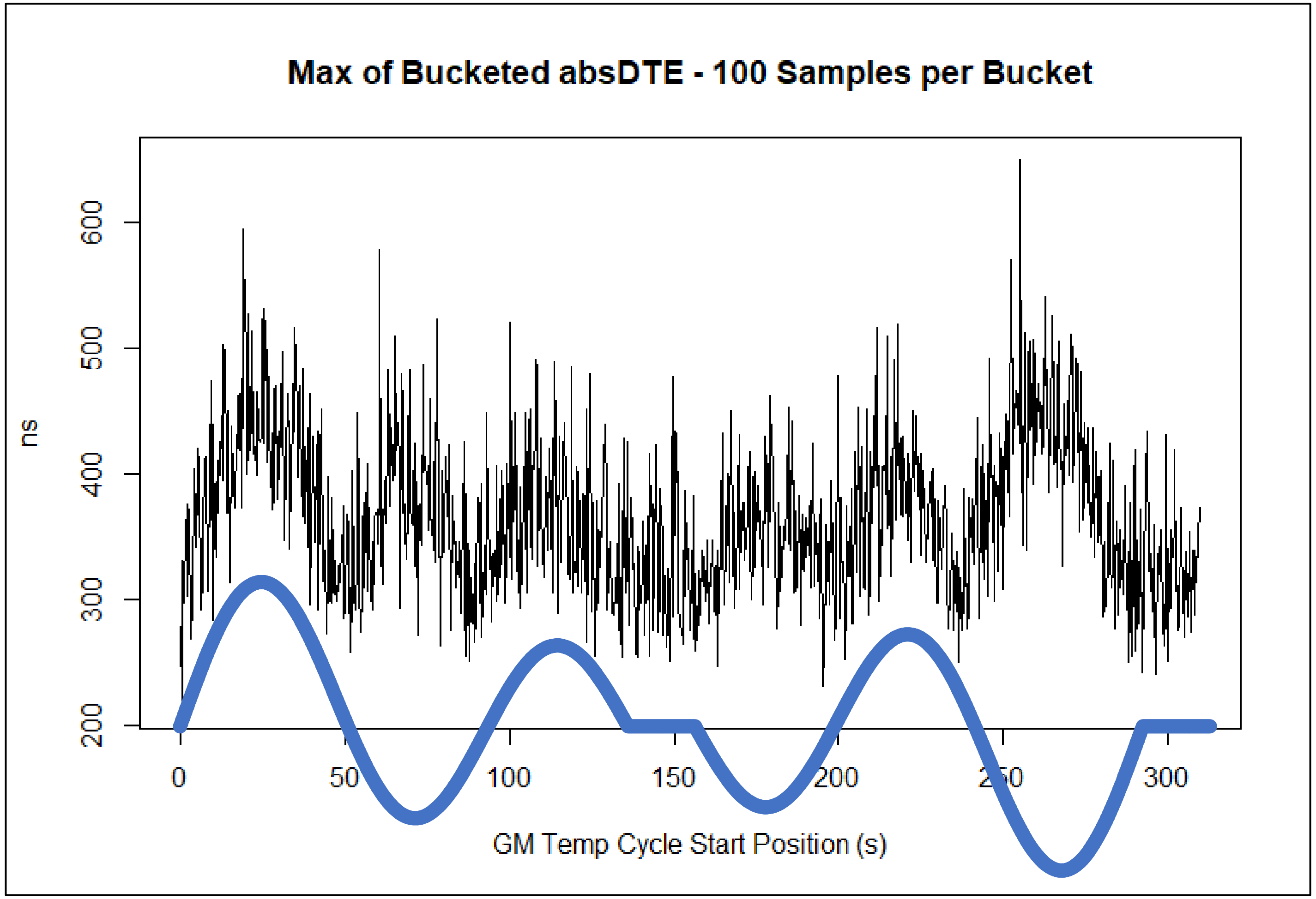


- Yes. Spikes immediately after discontinuities are clear.
- Errors are higher in period after discontinuity due to high ppm/s drift
- Useful to overlay ppm/s drift curve

Question: What does the equivalent graph look like for the Half-Sinusoidal Temp Ramp?

- Repeat with Half-Sinusoidal temp ramp
  - Half-Sinusoidal; 125 s Temp Ramp; GM Scale 1

Question: What does the equivalent graph look like for the Half-Sinusoidal Temp Ramp?

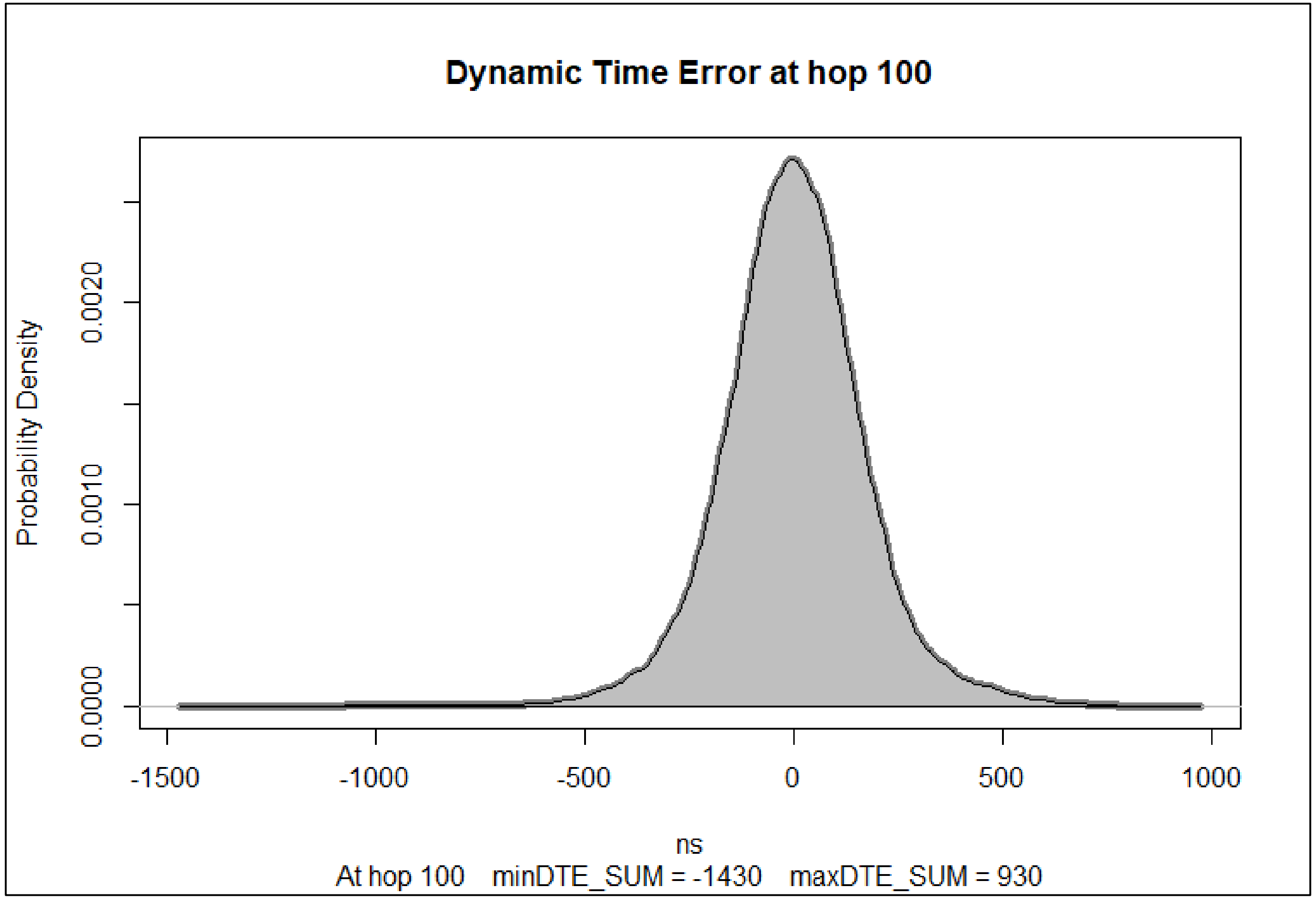


- Large spikes are absent.
- Again, useful to overlay ppm/s drift curve

Question: How much does a better oscillator at the GM buy you?

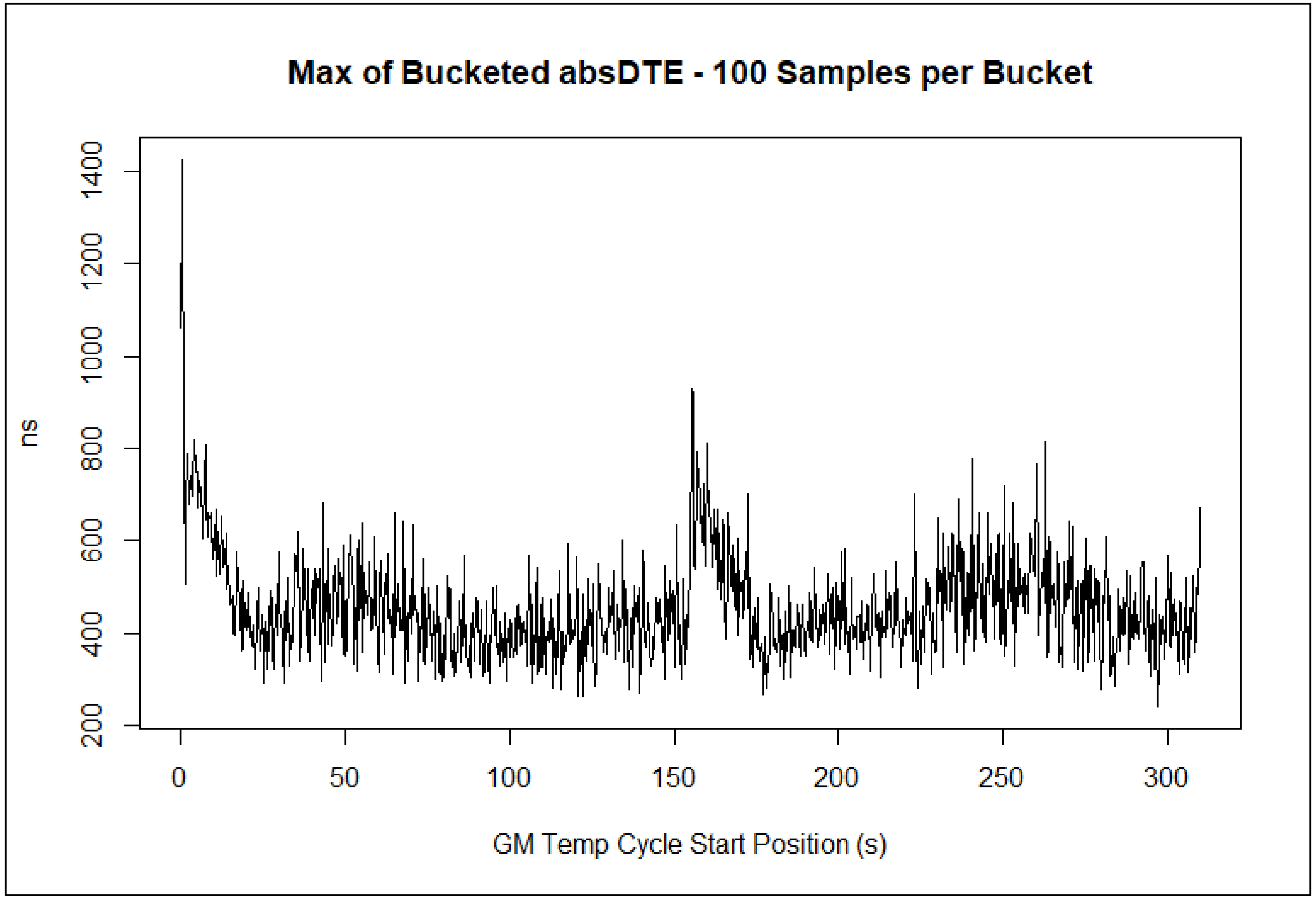
- Run the same analysis for both Quarter- and Half-Sinusoidal temperature ramps, but GM Scale of 0.5 (equivalent to ±25 ppm offset range).

Default: Quarter-Sinusoidal; 125 s Temp Ramp; GM Scale 1



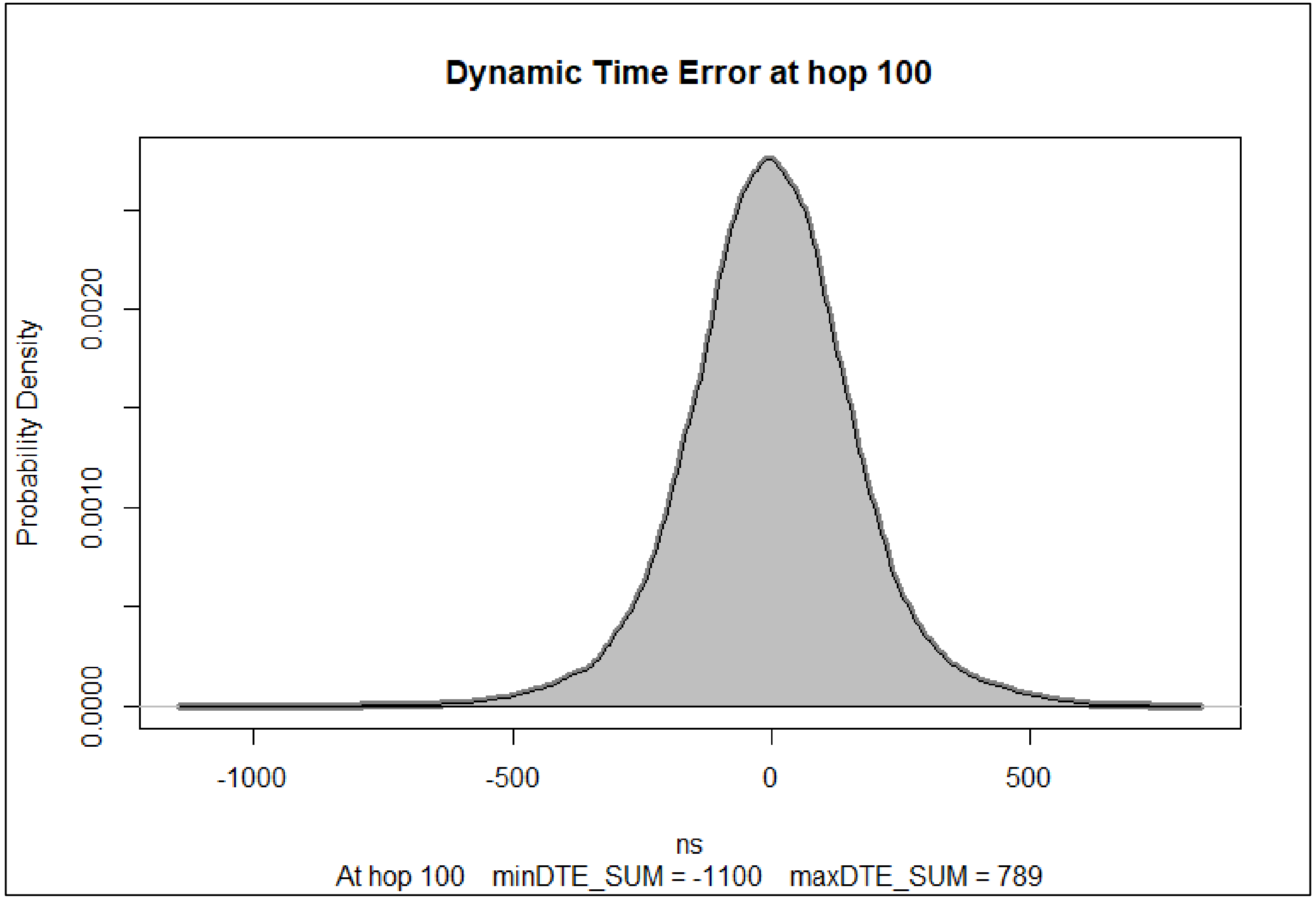
- Rerun with GM temp cycle start positions in order, equally space, across Temp Cycle
  - May be slightly different than random positions
- Min/Max -1400 to +900 ns (approx.)

Default: Quarter-Sinusoidal; 125 s Temp Ramp; GM Scale 1



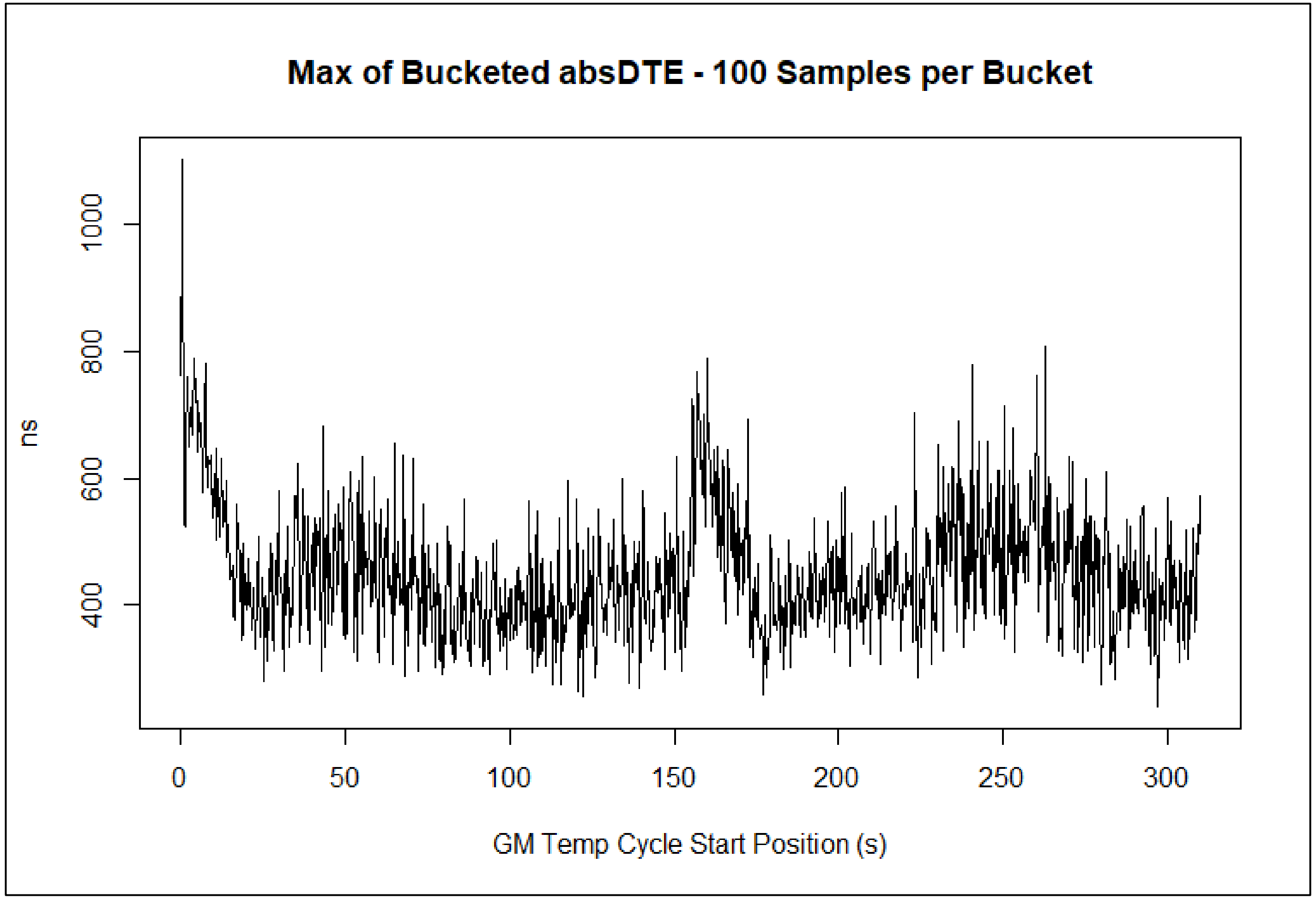
- When GM clock starting position is not in proximity to clock drift discontinuity, the worst case absolute error is between 600 and 800 ns; most of the time it’s between 300 and 600 ns.

Quarter-Sinusoidal; 125 s Temp Ramp; GM Scale 0.5



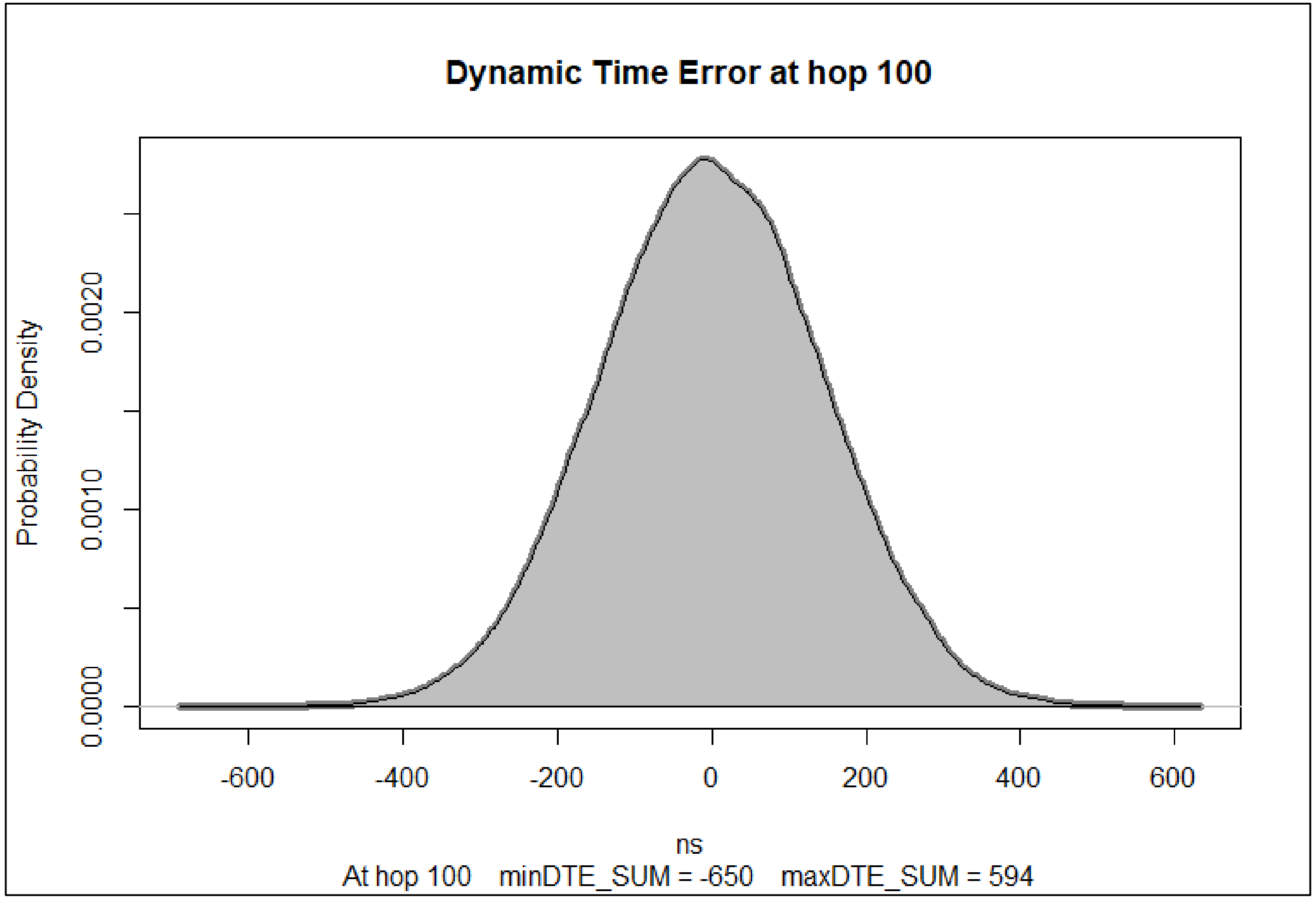
- Min/Max -1100 to +800 ns (approx.)
  - Min improved by 300 ns; Max improved by 100 ns

Quarter-Sinusoidal; 125 s Temp Ramp; GM Scale 0.5



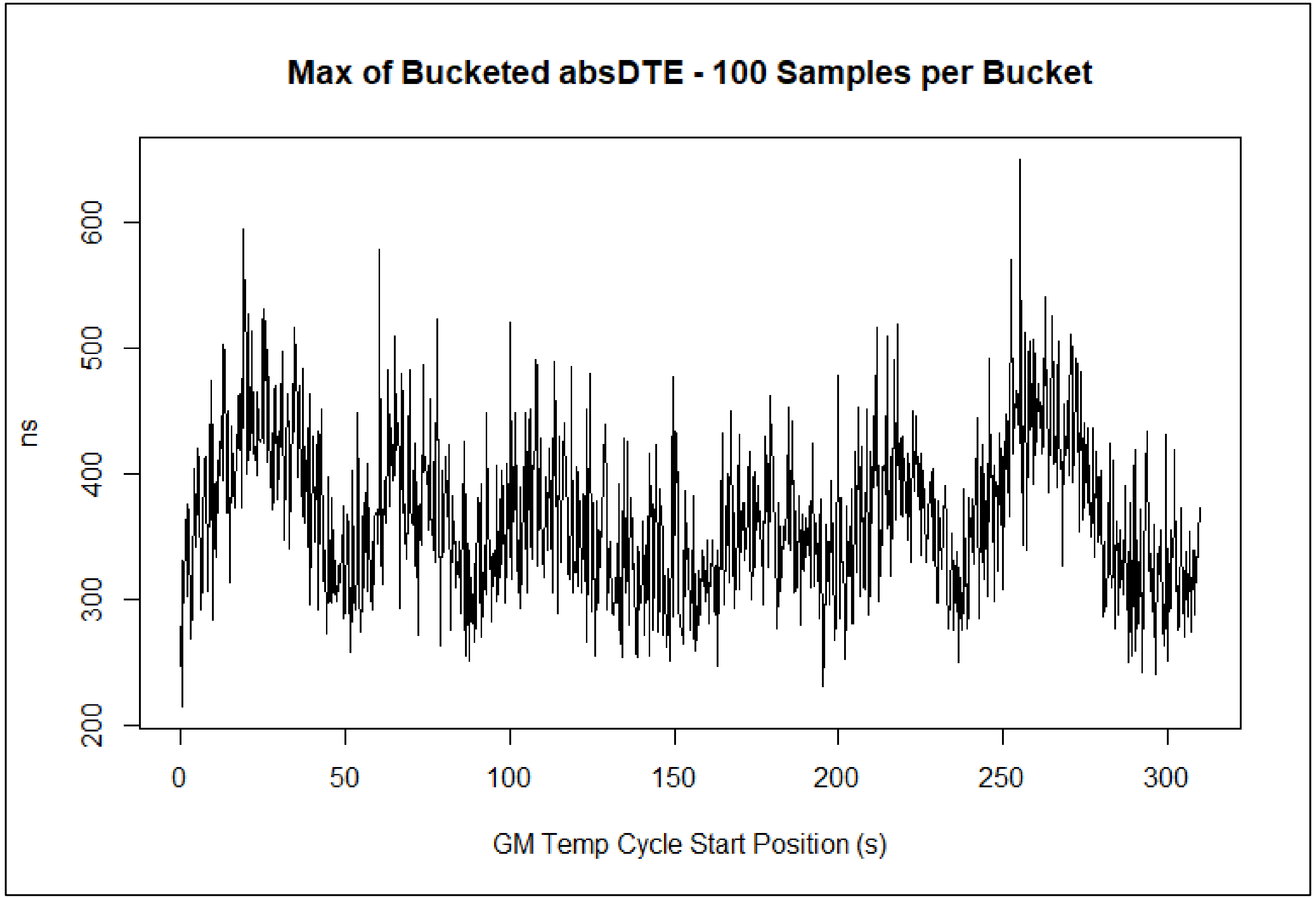
- When GM clock starting position is not in proximity to clock drift discontinuity, the worst case absolute error is between 600 and 800 ns; most of the time it's between 300 and 600 ns.
  - No significant change from GM Scale 1 for the areas that aren't close to clock drift discontiunities.

Half-Sinusoidal; 125 s Temp Ramp; GM Scale 1

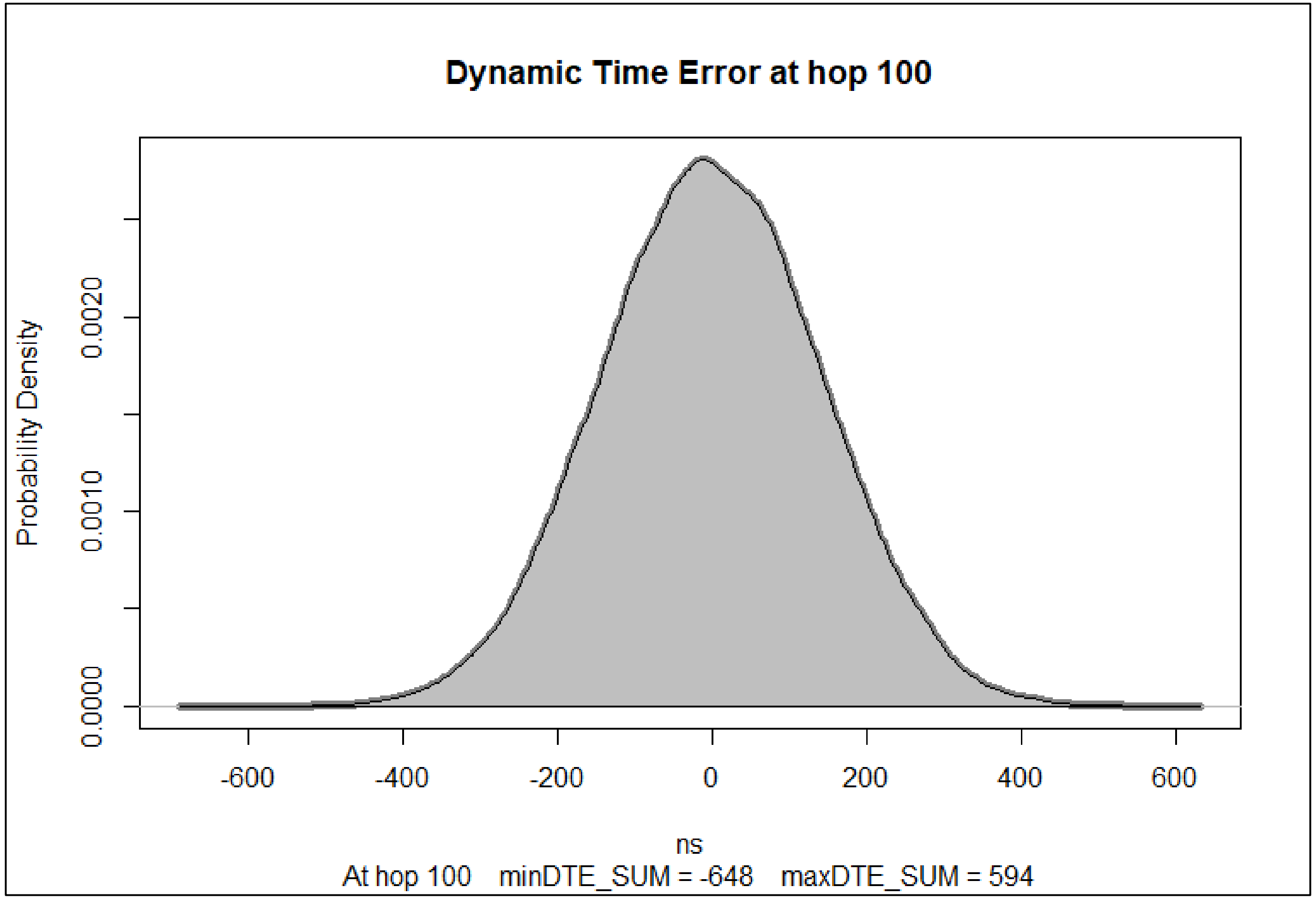


- Min/Max -650 to +590 ns (approx.)

Half-Sinusoidal; 125 s Temp Ramp; GM Scale 1

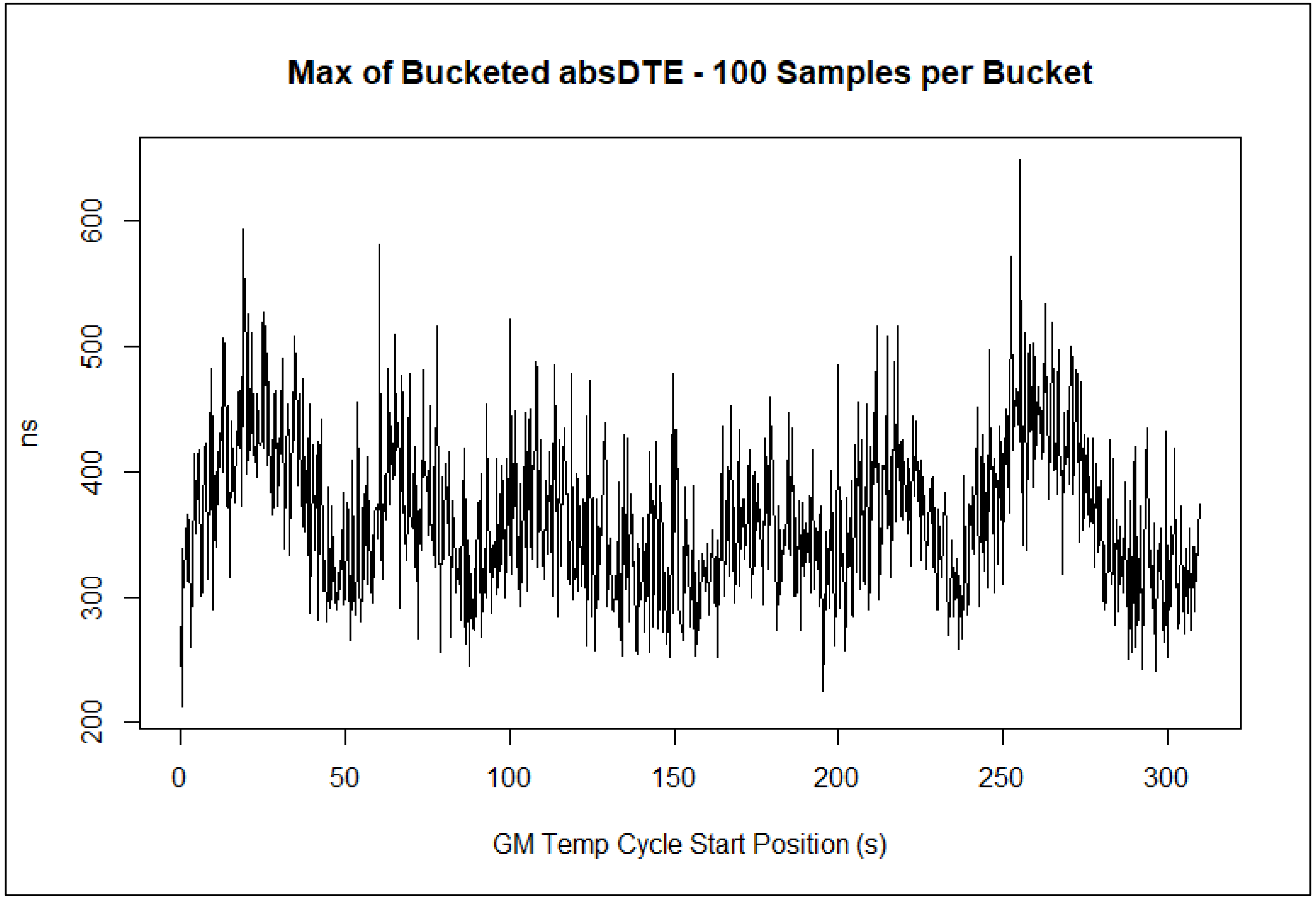


Half-Sinusoidal; 125 s Temp Ramp; GM Scale 0.5



- Min/Max -650 to +600 ns (approx.)
  - No significant change

Half-Sinusoidal; 125 s Temp Ramp; GM Scale 0.5



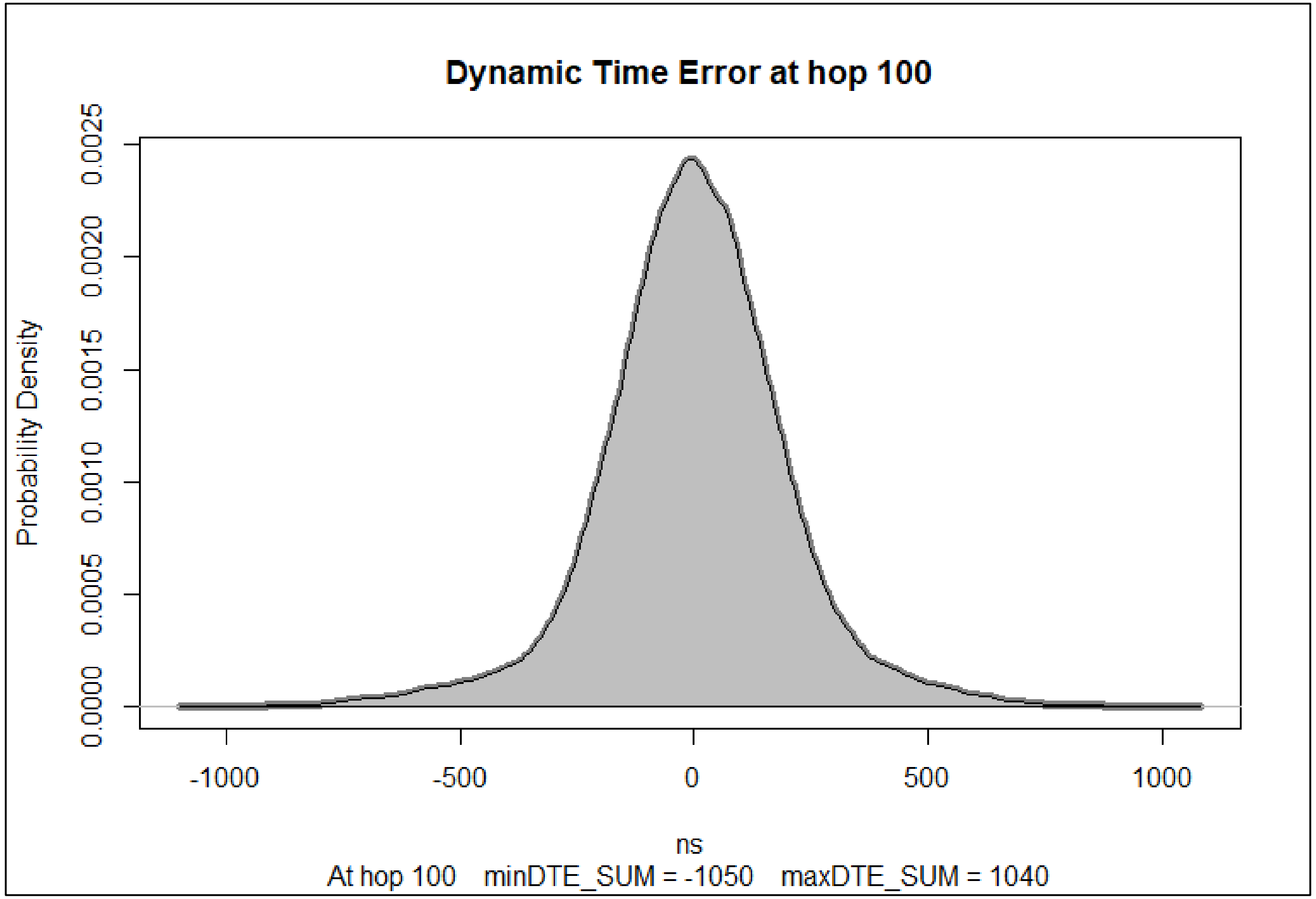
Conclusion: a better GM oscillator mainly buy improvements when there are discontinuities

- Discontinuities where the worst cases occur. A better crystal reduces the size of the discontinuities.
- If temperature ramp doesn't include discontinuities, the benefit is minimal.
- For the configurations we're looking at, discontinuities cause Time Sync error to exceed goal (dTE worst case is greater than total TE budget)

Question: how much does NRR & RR drift tracking and error compensation buy you?

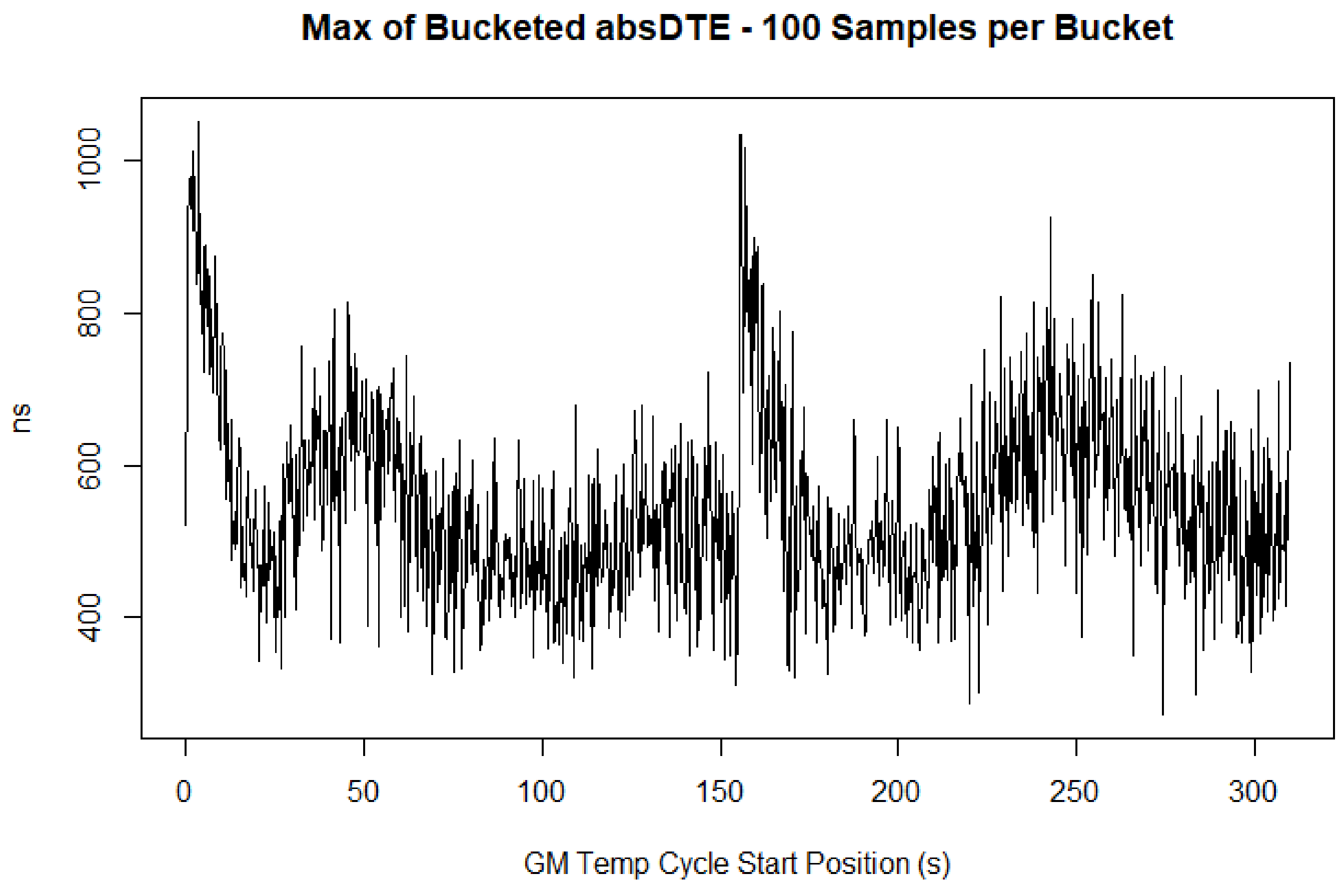
- Run the same analysis for both Quarter- and Half-Sinusoidal temperature ramps, but without the tracking and compensation algorithms.
  - Quarter-Sinusoidal with GM Scale 0.5
  - Half-Sinusoidal with GM Scale 1

Quarter-Sinusoidal; No NRR/RR Tracking; 125 s Temp Ramp; GM Scale 0.5



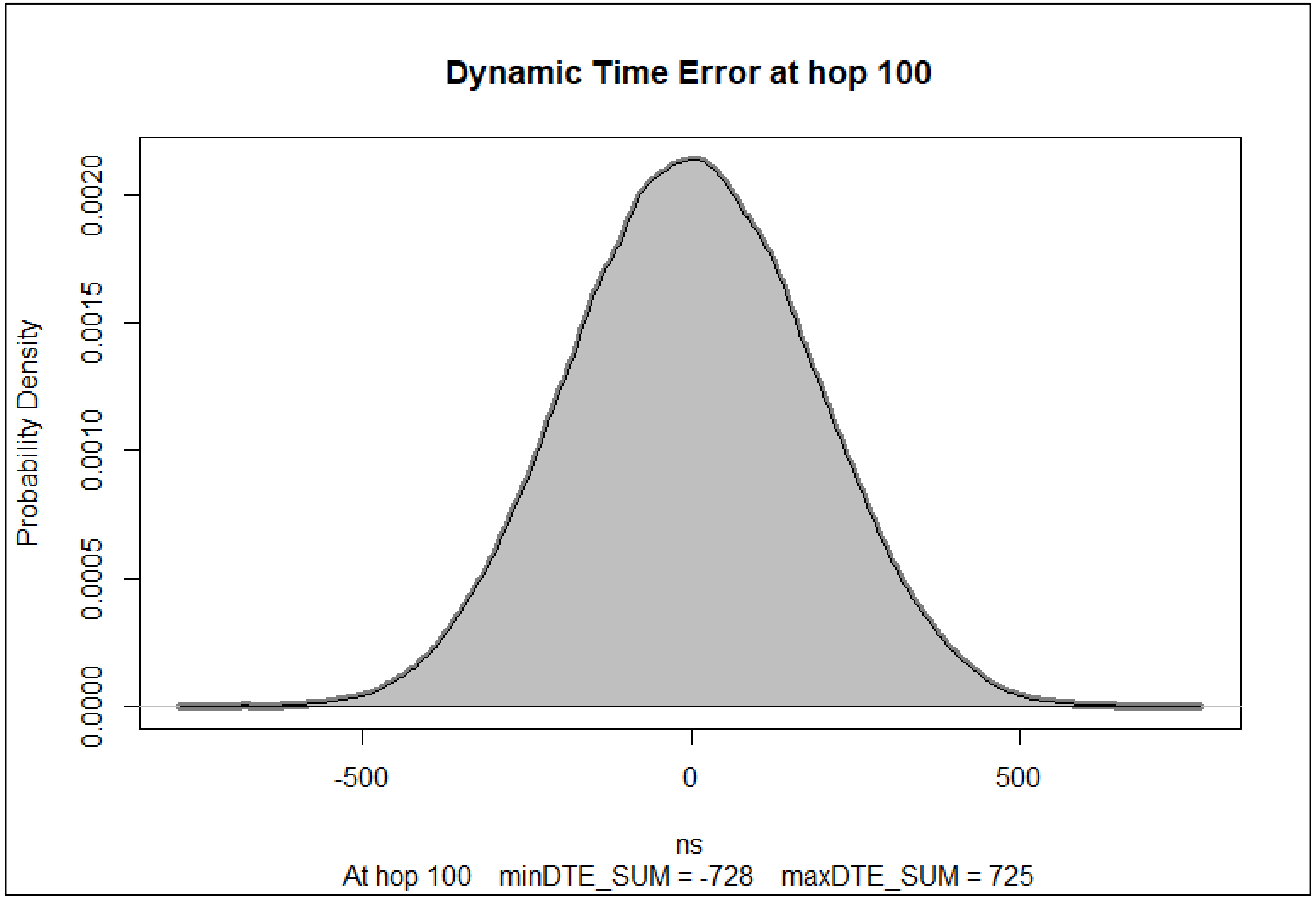
- Min/Max ±1050 ns
  - With tracking was -1100 to +800 ns

Quarter-Sinusoidal; No NRR/RR Tracking; 125 s Temp Ramp; GM Scale 0.5



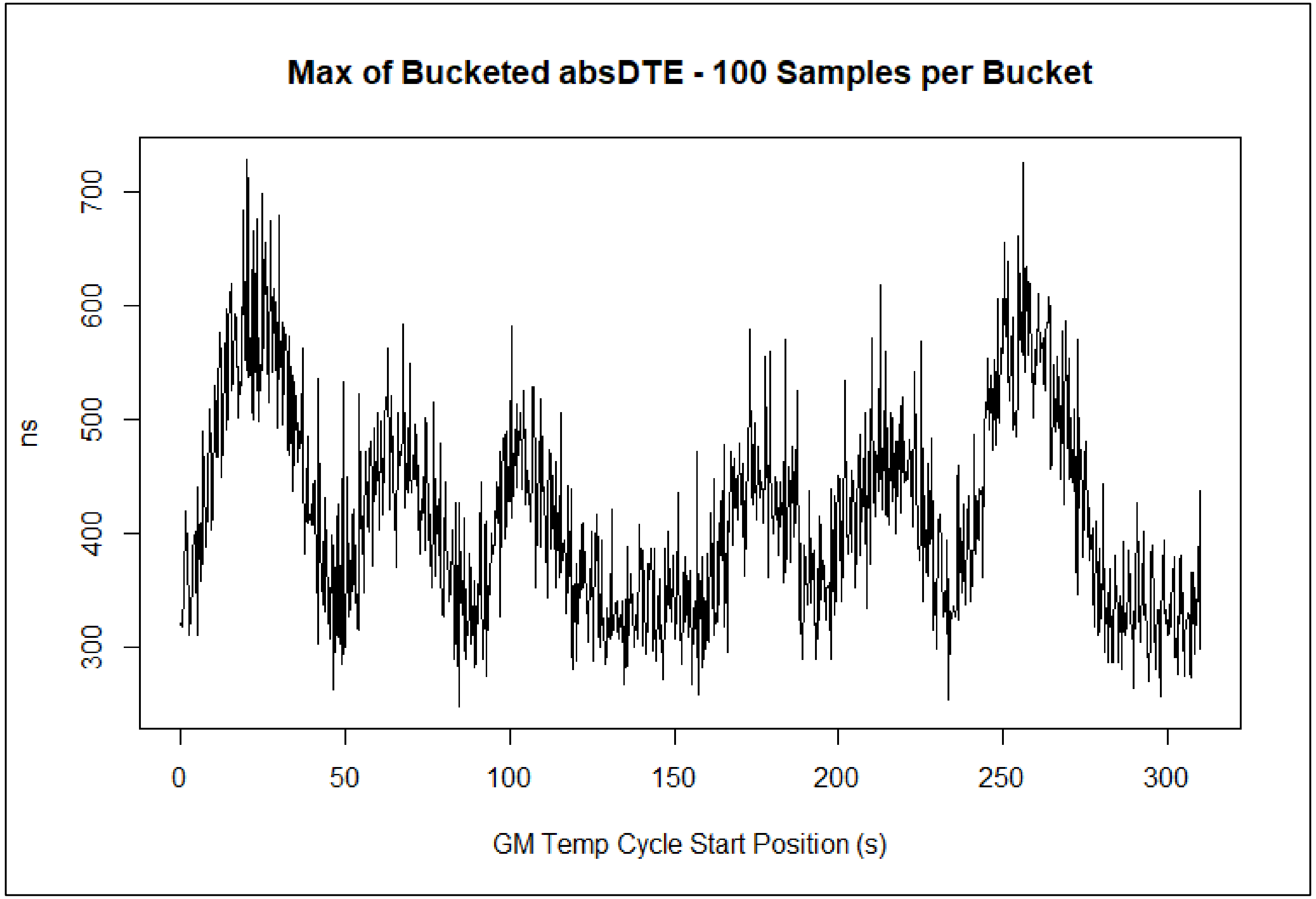
- Appears to be 100 to 200 ns worse across the entire GM Temp Ramp

Half-Sinusoidal; No NRR/RR Tracking; 125 s Temp Ramp; GM Scale 1



- Min/Max ±725 ns (approx.)
  - With tracking was -650 to +590 ns

Half-Sinusoidal; No NRR/RR Tracking; 125 s Temp Ramp; GM Scale 1

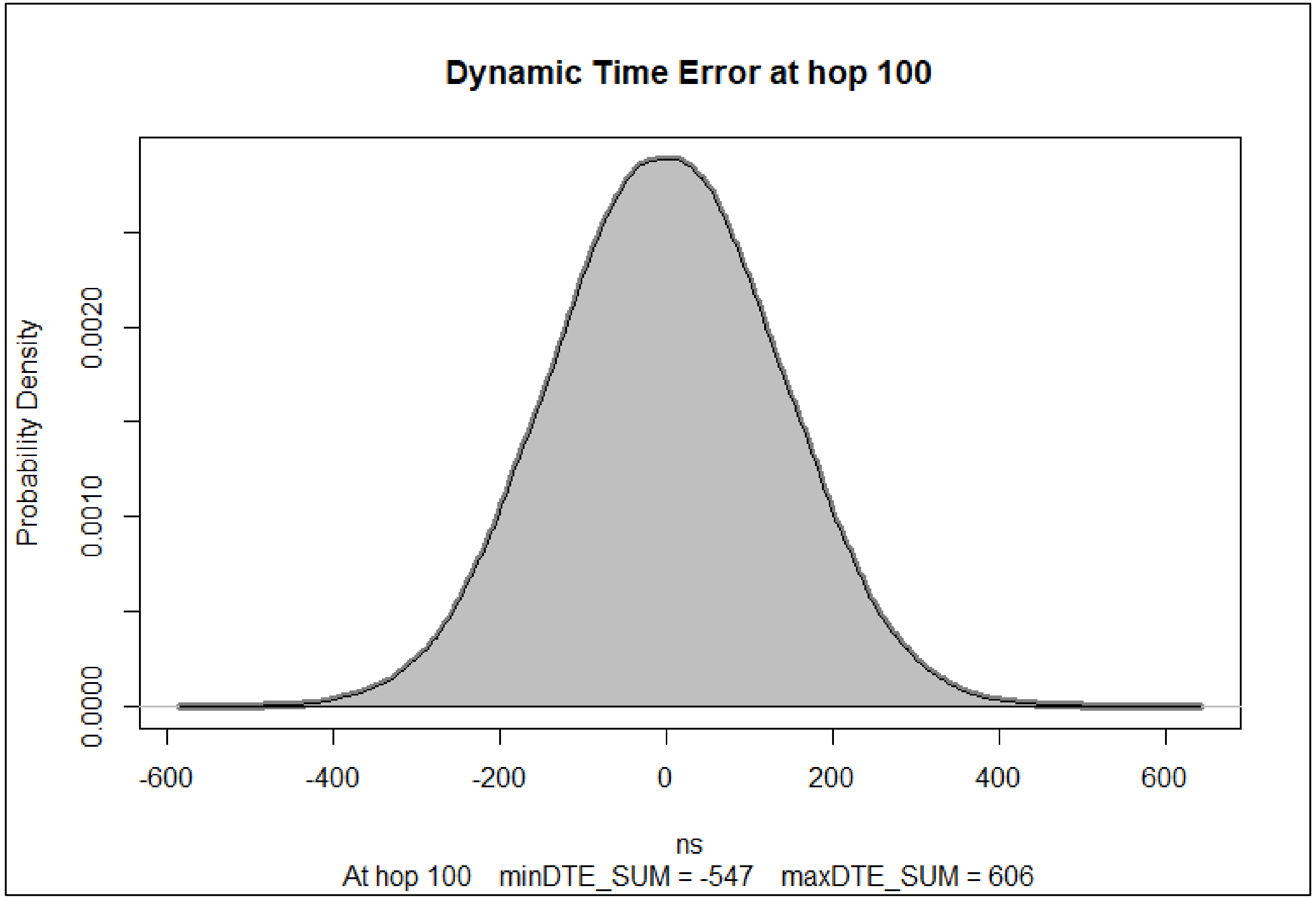


- Appears to be 100 to 150 ns worse across the entire GM Temp Ramp

Question: Switching off NRR / RR tracking and error compensation makes things worse. Can increasing it make things better?

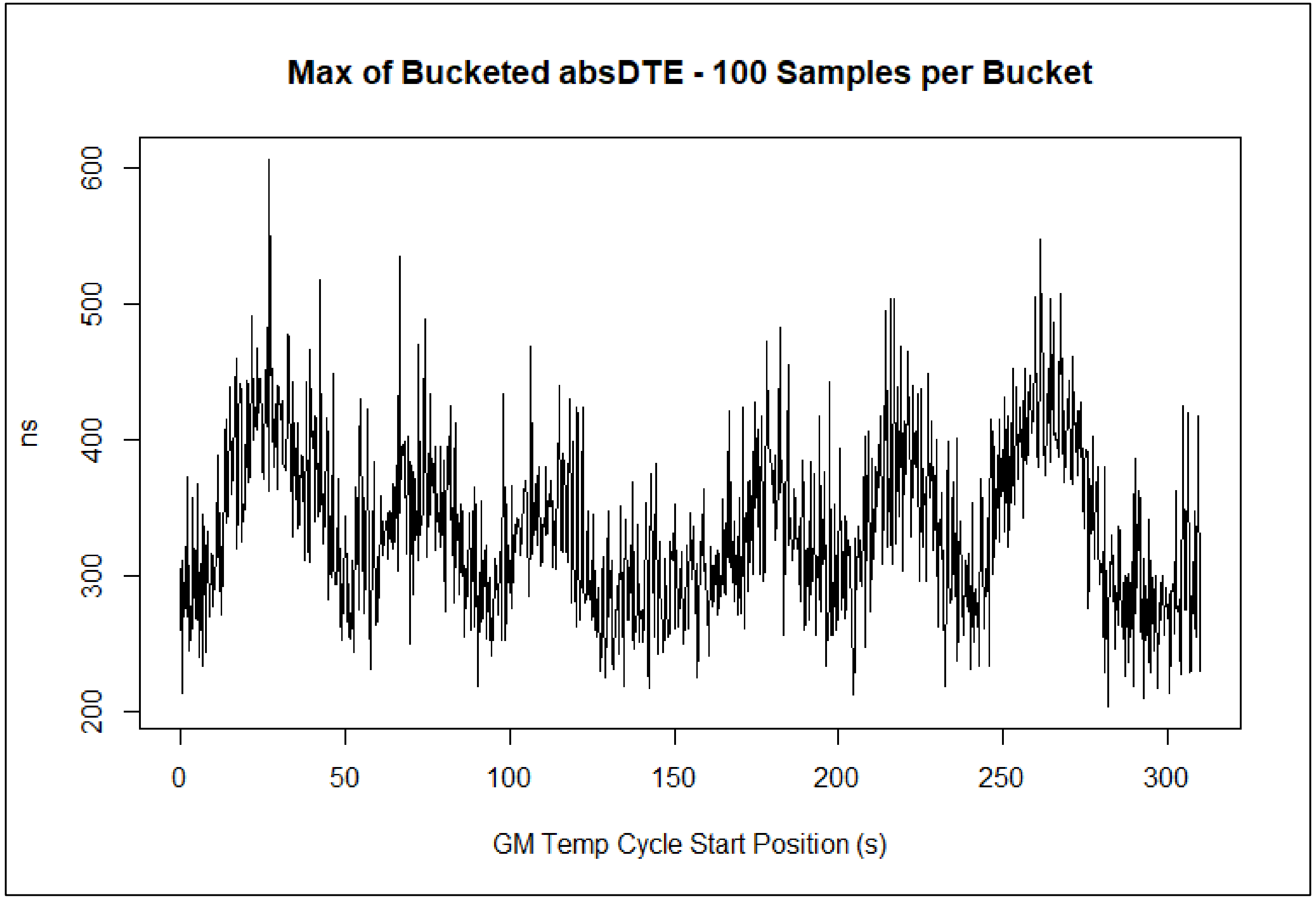
- Run simulations with mNRRcompNAP = 6 and then 8
  - Half-Sinusoidal; 125 s Temp Ramp; GM Scale 1

Half-Sinusoidal; mNRRcompNAP 6; 125 s Temp Ramp; GM Scale 1



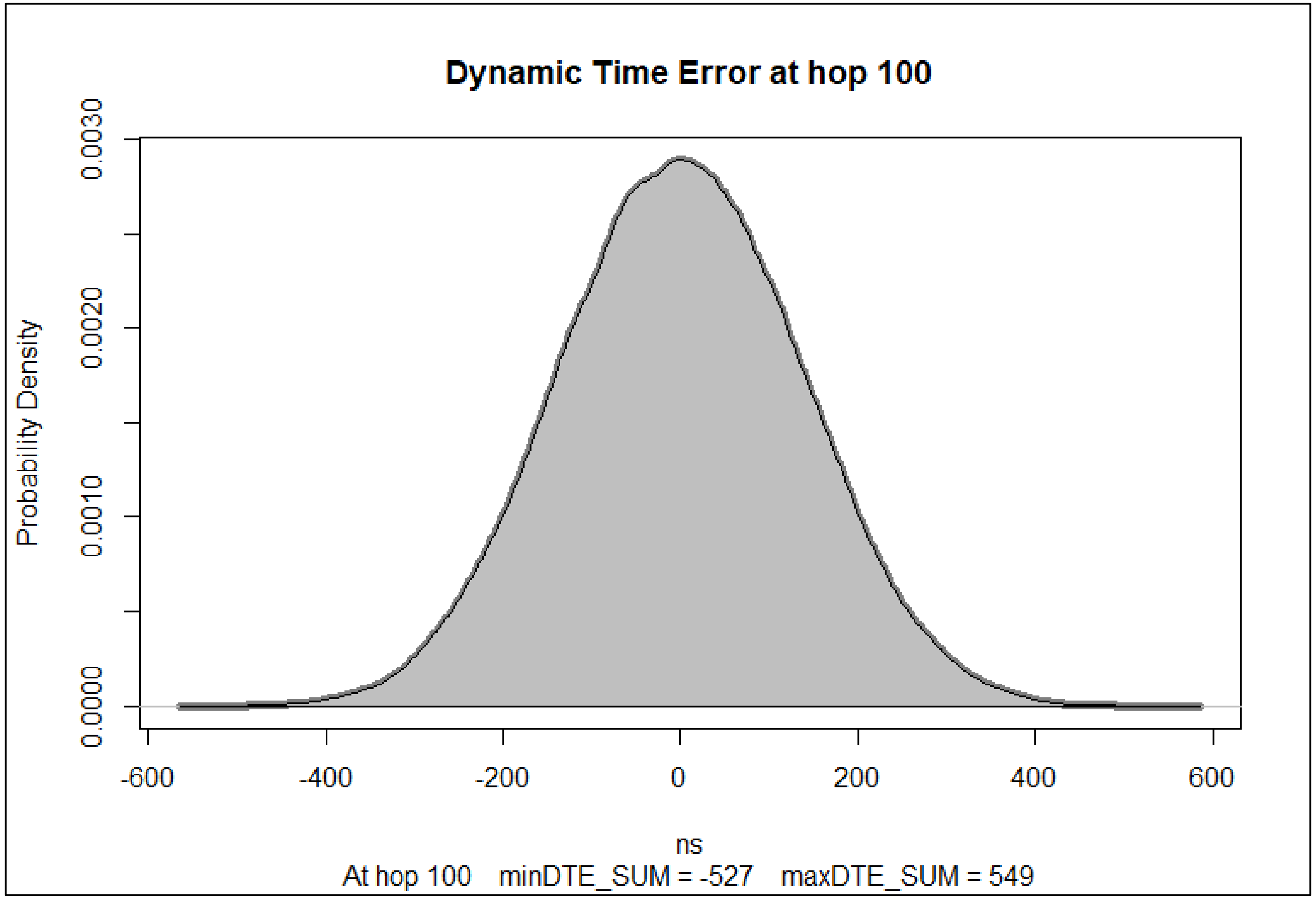
- Min/Max -550 to +610 ns (approx.) a 40 ns (approx.) improvement.
  - With mNRRcompNAP 4 was -650 to +590 ns

Half-Sinusoidal; mNRRcompNAP 6; 125 s Temp Ramp; GM Scale 1



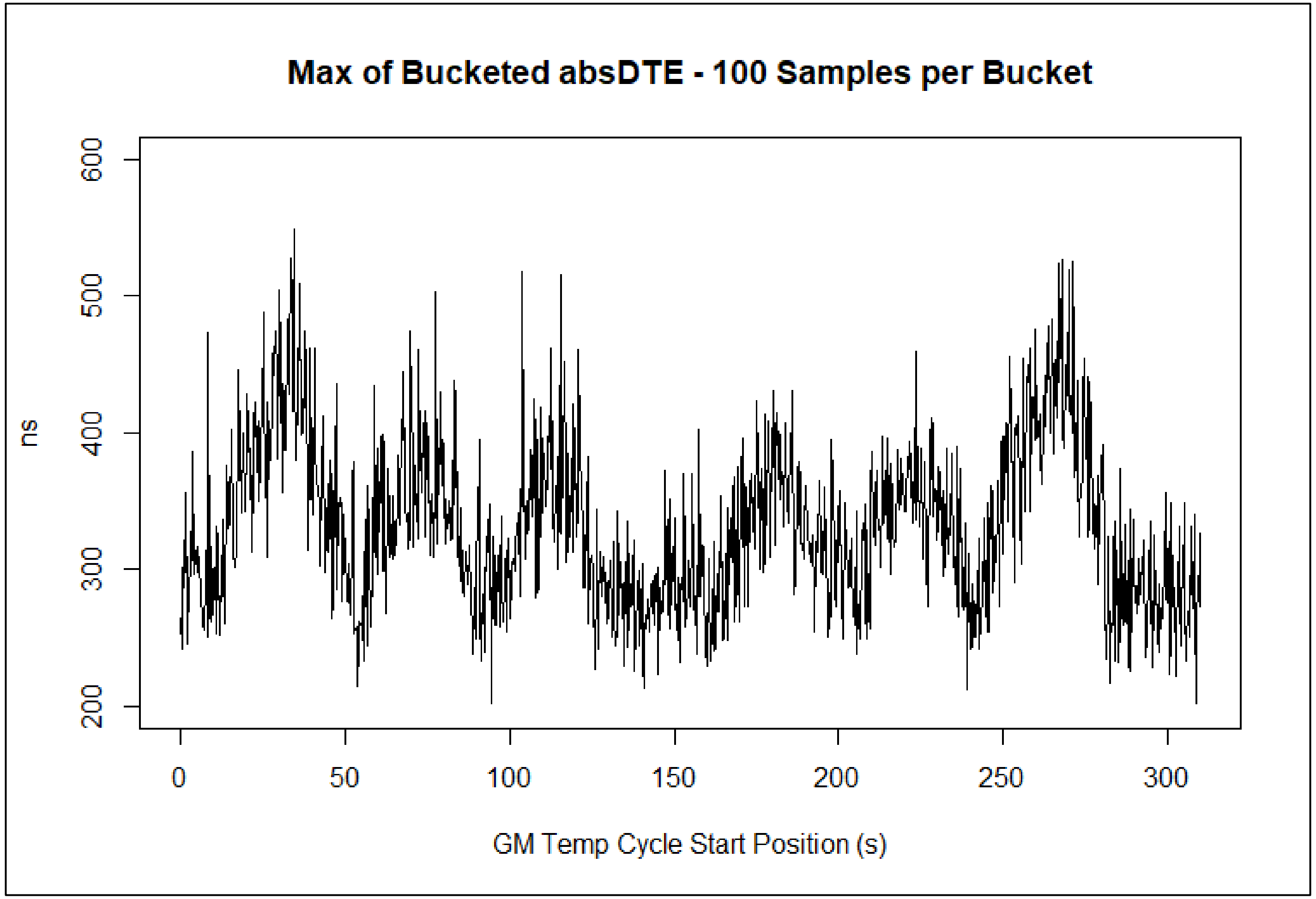
- Confirms approx. 50 ns improvement across the board.

Half-Sinusoidal; mNRRcompNAP 8; 125 s Temp Ramp; GM Scale 1



- Min/Max -539 to +550 ns (approx.) an additional 20 to 50 ns (approx.) improvement.
  - With mNRRcompNAP 6, was -550 to +610 ns

Half-Sinusoidal; mNRRcompNAP 8; 125 s Temp Ramp; GM Scale 1

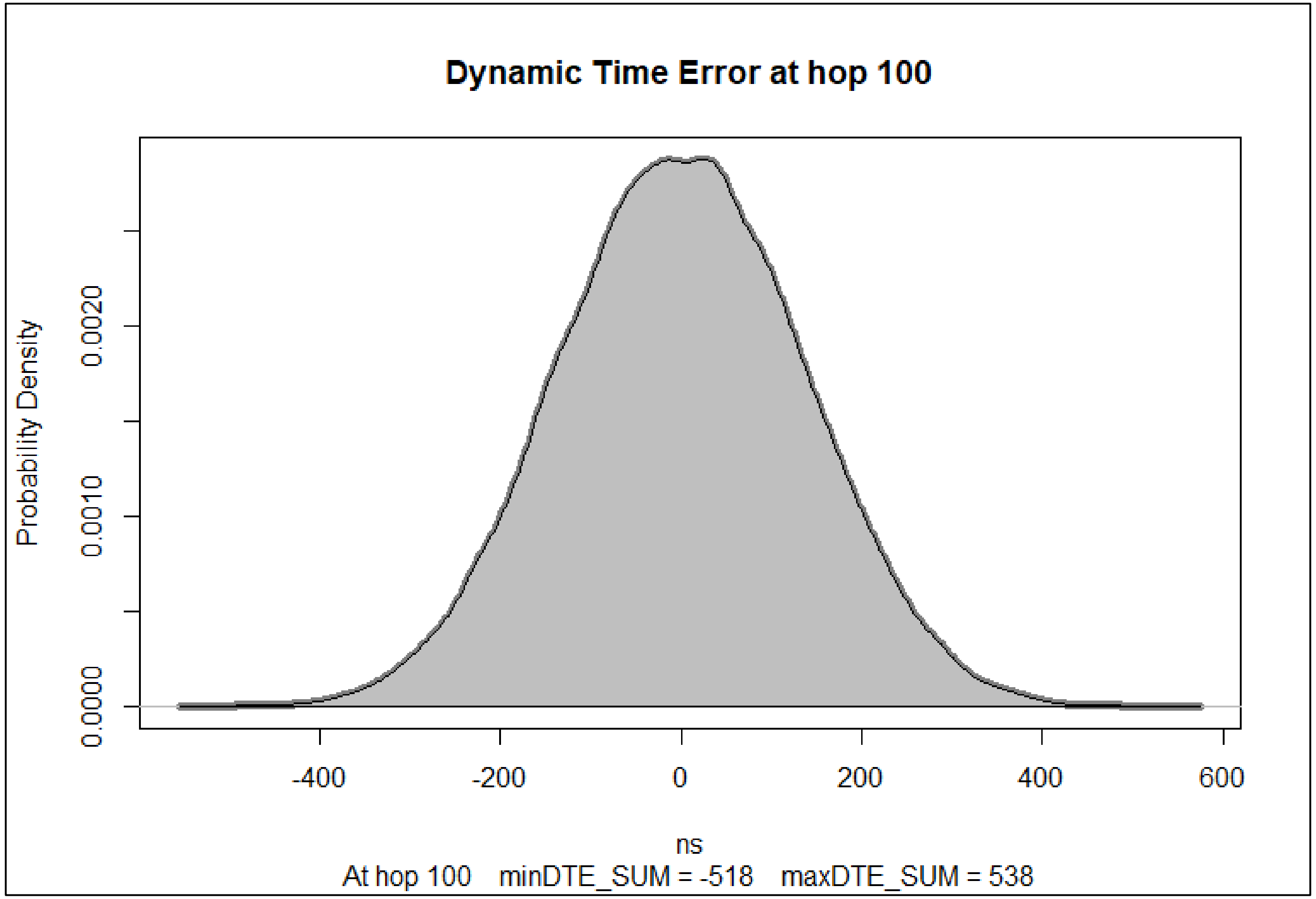


- Does appear to shave off some of the more extreme errors.

Question: Any benefit to increasing mNRRsmoothingNA?

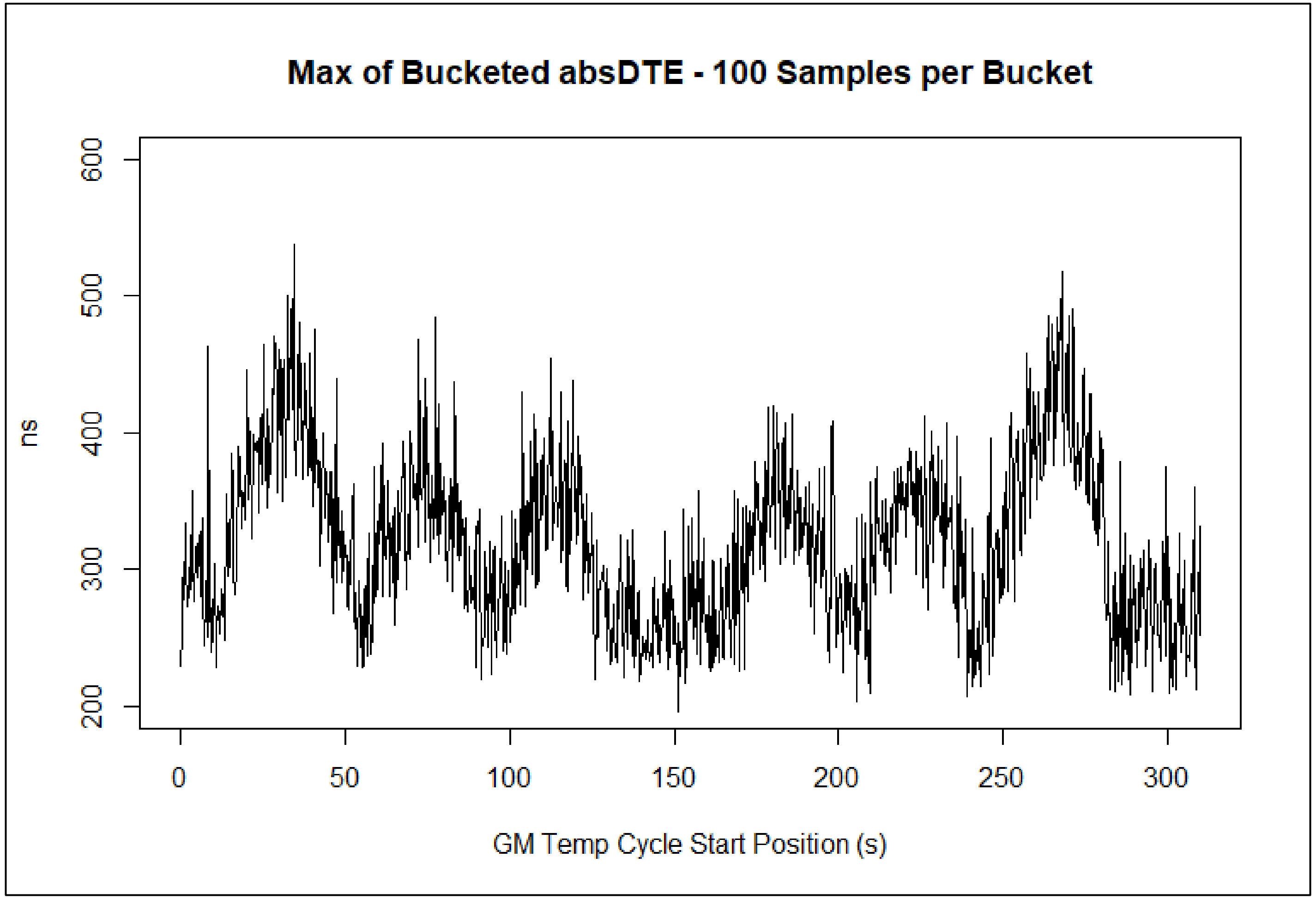
- Run simulations with mNRRsmoothing = 6 and then 8
    - Half-Sinusoidal; 125 s Temp Ramp; GM Scale 1; mNRRcompNAP 8

Half-Sinusoidal; mNRRcompNAP 8; mNRRsmoothingNA 6; 125 s Temp Ramp; GM Scale 1



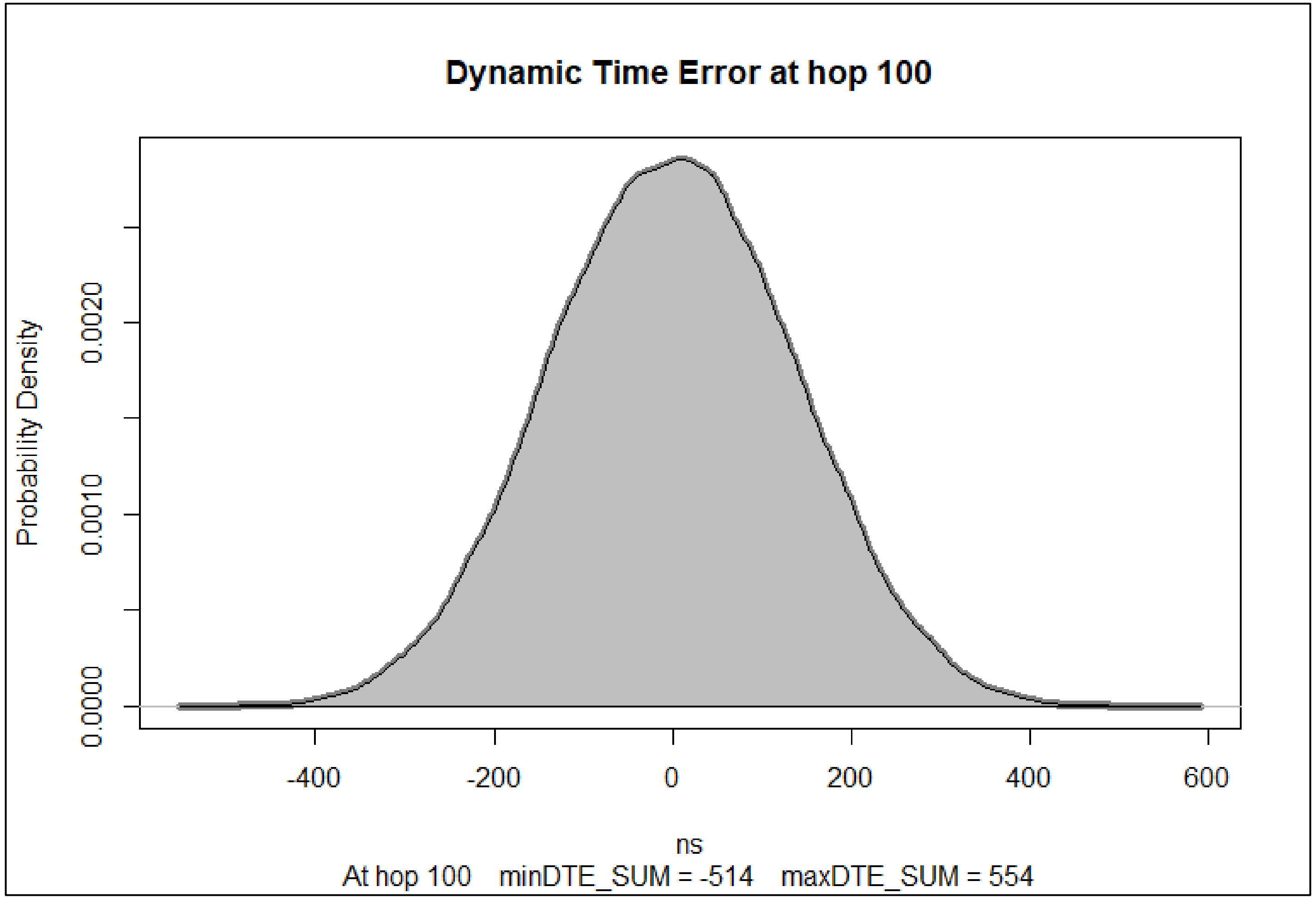
- Min/Max -518 to +538 ns (approx.) a 15 to 20 ns (approx.) improvement.
  - With mNRRsmoothingNA 4 was -539 to +550 ns

Half-Sinusoidal; mNRRcompNAP 8; mNRRsmoothingNA 6; 125 s Temp Ramp; GM Scale 1



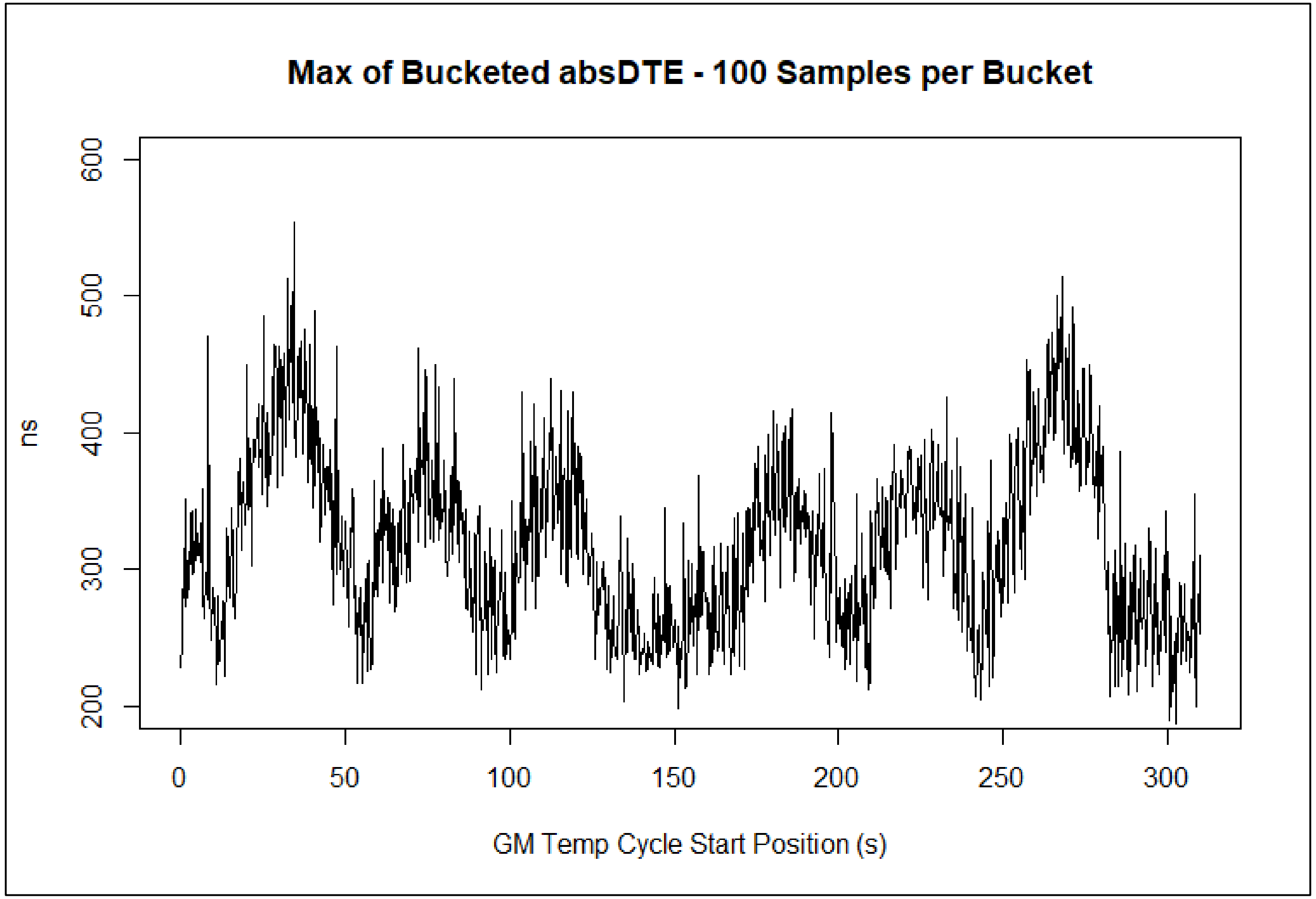
- Confirms approx. 50 ns improvement across the board.

Half-Sinusoidal; mNRRcompNAP 8; mNRRsmoothingNA 8; 125 s Temp Ramp; GM Scale 1



- Min/Max -515 to +554 ns (approx.) which is slightly worse, although probably within margin of error
  - With mNRRsmoothingNA 6 4 was -518 to +538 ns

Half-Sinusoidal; mNRRcompNAP 8; mNRRsmoothingNA 8; 125 s Temp Ramp; GM Scale 1



- No visible difference vs. mNRRsmoothing 6

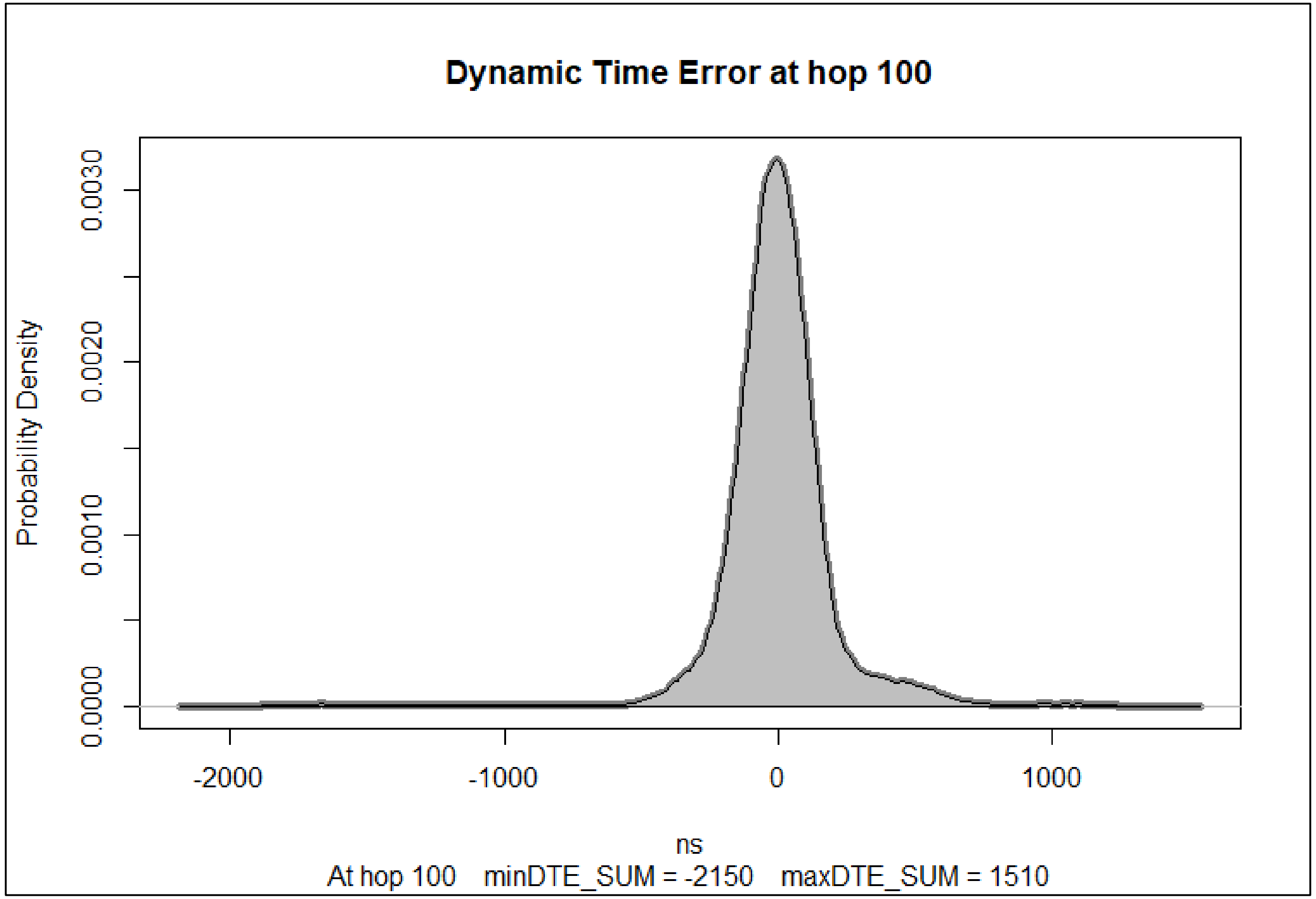
Simulations Suggest Optimised Configuration…

- mNRRcompNAP 8, so for NRR drift measurement…
  - For first measurement…
    - Look back 8 Sync messages for initial NRR calculation (N)
    - Take average of past 8 calculations (A)
  - For second measurement, do the same thing but…
    - Start 16 Sync messages in the past (P)
- mNRRsmoothingNA 8, so for compensated mNRR measurement…
  - Look back 8 Sync messages for initial calculation (N)
  - Take average of past 8 calculations
  - Allows reuse of initial calculations from NRR drift measurement

Question: Do these settings make the system less robust against potential discontinuities?

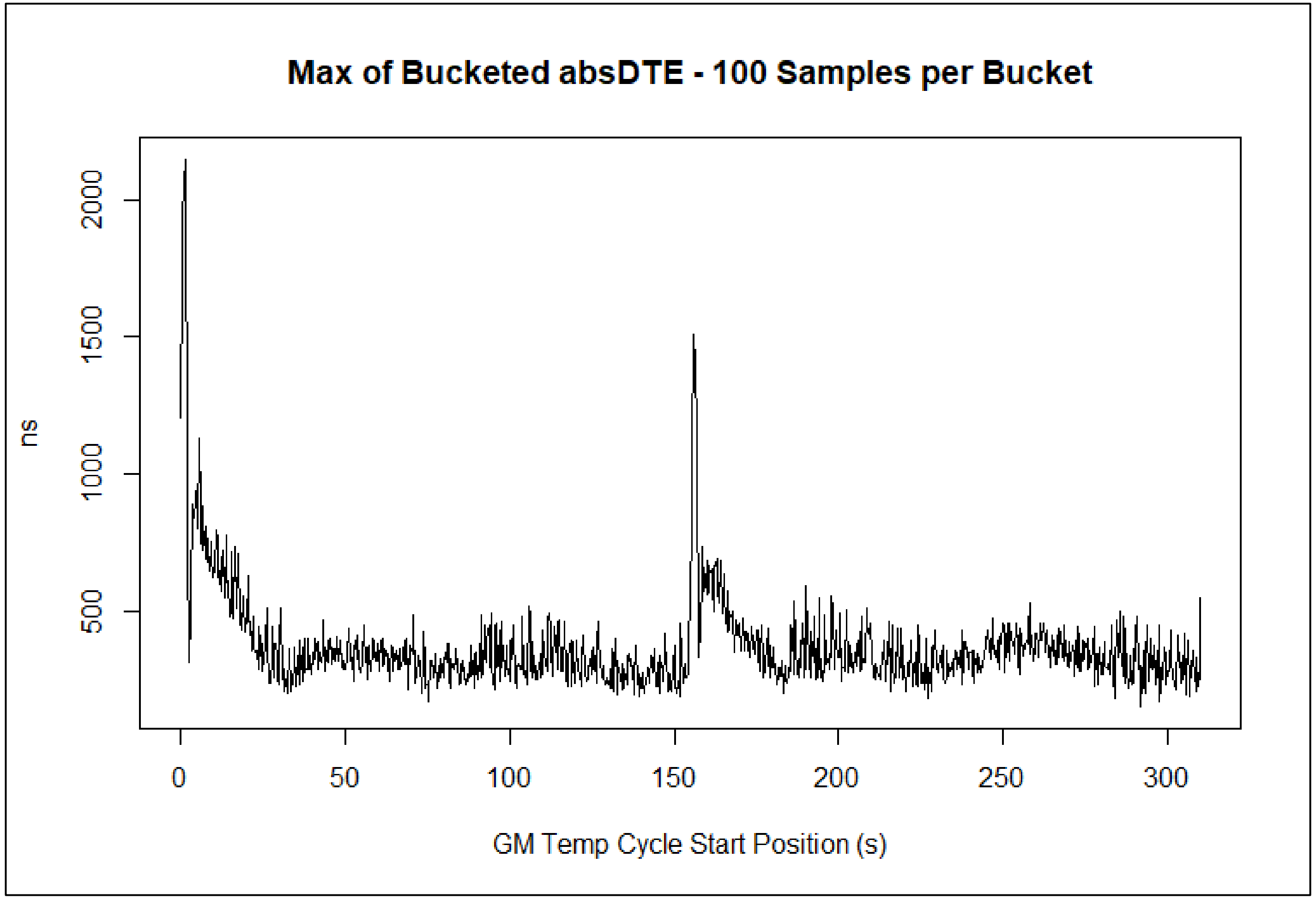
- mNRRcompNAP 8 means using data from past 32 Sync messages, i.e. past 4 seconds (with Sync Interval 125 ms)
- Although the simulation with Half-Sinusoidal temp ramp does not include discontinuities, there may be concerns that this optimisation makes the system less robust against behaviours the simulation does not fully cover.
- Run simulation with optimised settings, but Quarter-Sinusoidal temperature ramp and GM Scale 0.5, and see how it compares with initial simulation results

Quarter-Sinusoidal; mNRRcompNAP 8; mNRRsmoothingNA 8; 125 s Temp Ramp; GM Scale 0.5



- Min/Max -2150 to +1500 ns (approx.) which is approx. 2x worse than with mNRRcompNAP 4 & mNRRsmoothingNA 4
  - with mNRRcompNAP 4, mNRRsmoothingNA 4 was -1100 to +800 ns

Quarter-Sinusoidal; mNRRcompNAP 8; mNRRsmoothingNA 8; 125 s Temp Ramp; GM Scale 0.5



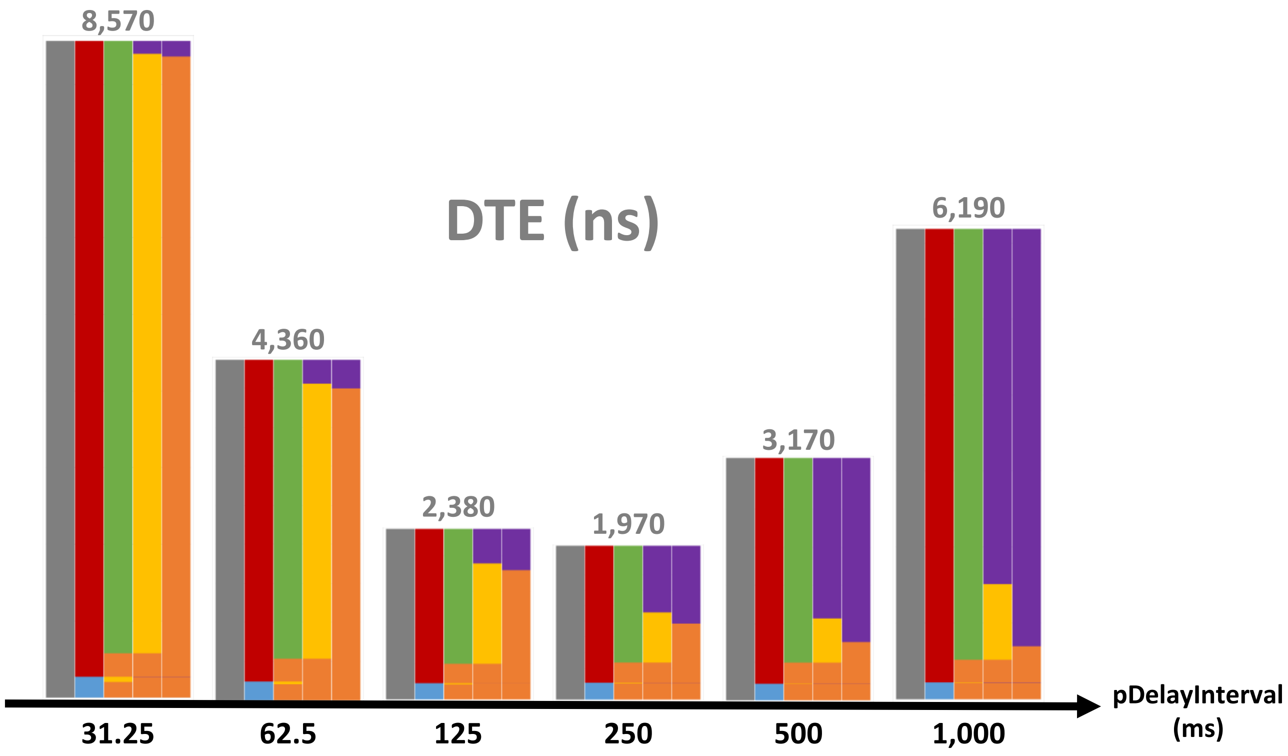
- Increase appears to be driven entirely by spikes following discontinuities
- But spikes appeared to be half the size (and the same size) for both…
  - mNRRcompNAP 4 mNRRsmoothingNAP 4
  - mNRRcompNAP 4 mNRRsmoothingNAP 0 (no compensation)
- So…what is going on?

Question: What is going on?

- Key observation: doubling mNRRsmoothingNA (from 4 to 8) almost exactly doubled the size of the spikes in Time Sync Error following a discontinunity.
- Increasing mNRRsmoothingNA is (almost) equivalent to increasing the Pdelay Interval when using Pdelay_Resp to measure NRR as far as the balance between error due to Timestamp vs. error due to Clock Drift
  - See slide 72 from [3] (way back in November 2021)…

pDelayInterval Sensitivity Analysis

From [3]



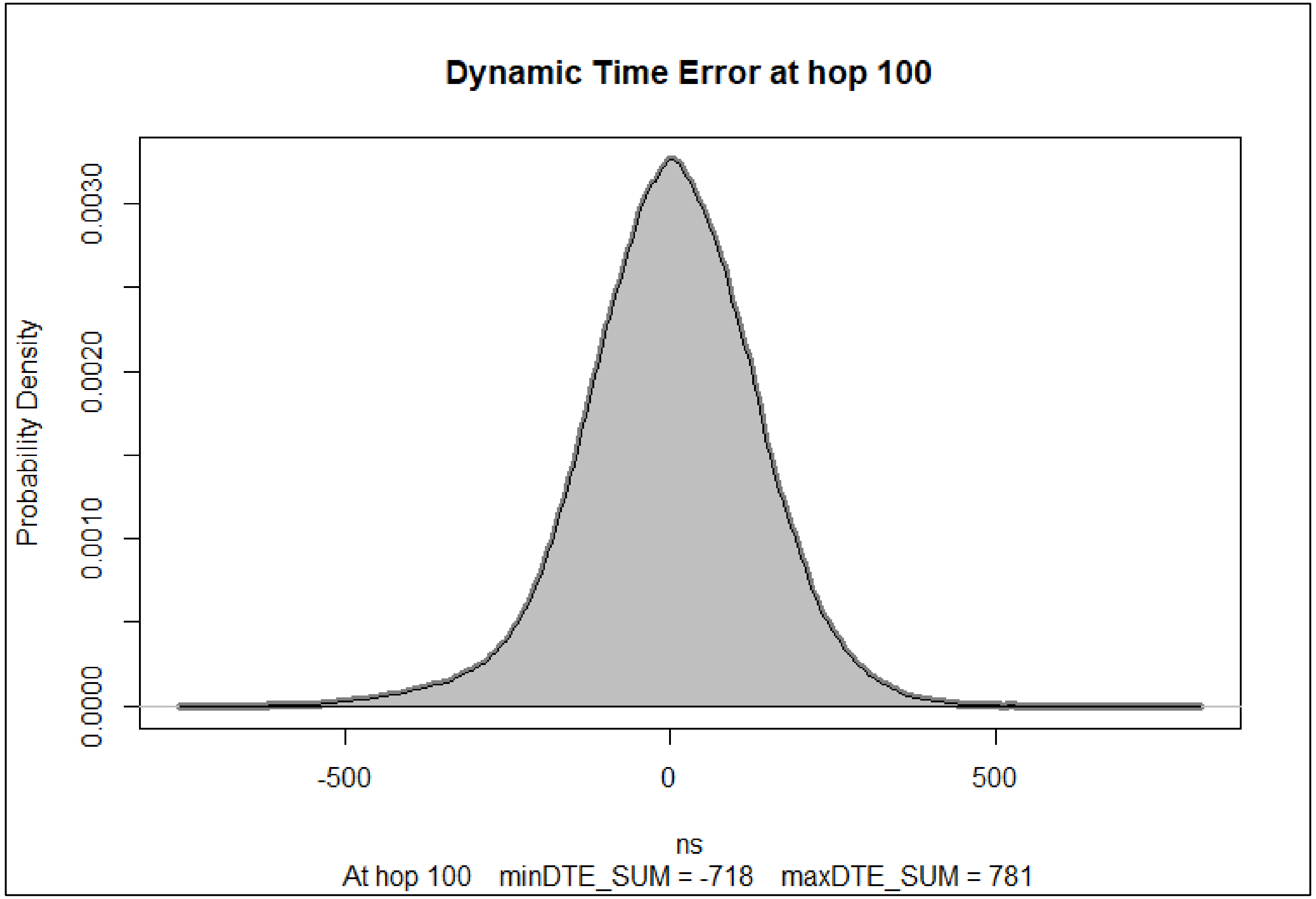
Question: What is going on?

- Key observation: doubling mNRRsmoothingNA (from 4 to 8) almost exactly doubled the size of the spikes in Time Sync Error following a discontinunity.
- Increasing mNRRsmoothingNA is (almost) equivalent to increasing the Pdelay Interval when using Pdelay_Resp to measure NRR as far as the balance between error due to Timestamp vs. error due to Clock Drift
  - See slide 72 from [3] (way back in November 2021)
- Balance is different when drift tracking and error compensation algorithm reduces the relative contribution to overall time error from clock drift (purple in the diagram), but…
- Immediately after a discontinuity the drift tracking and error compensation algorithm is ineffective and behaviour is dictated by the amount of error due to clock drift
  - If the interval (now Sync Interval, not Pdelay Interval) and mNRRsmoothingNA means that error due to clock drift is comparable to error from Timestamp error, doubling mNRRsmoothingNA will double Time Sync Error.

Hypothesis:

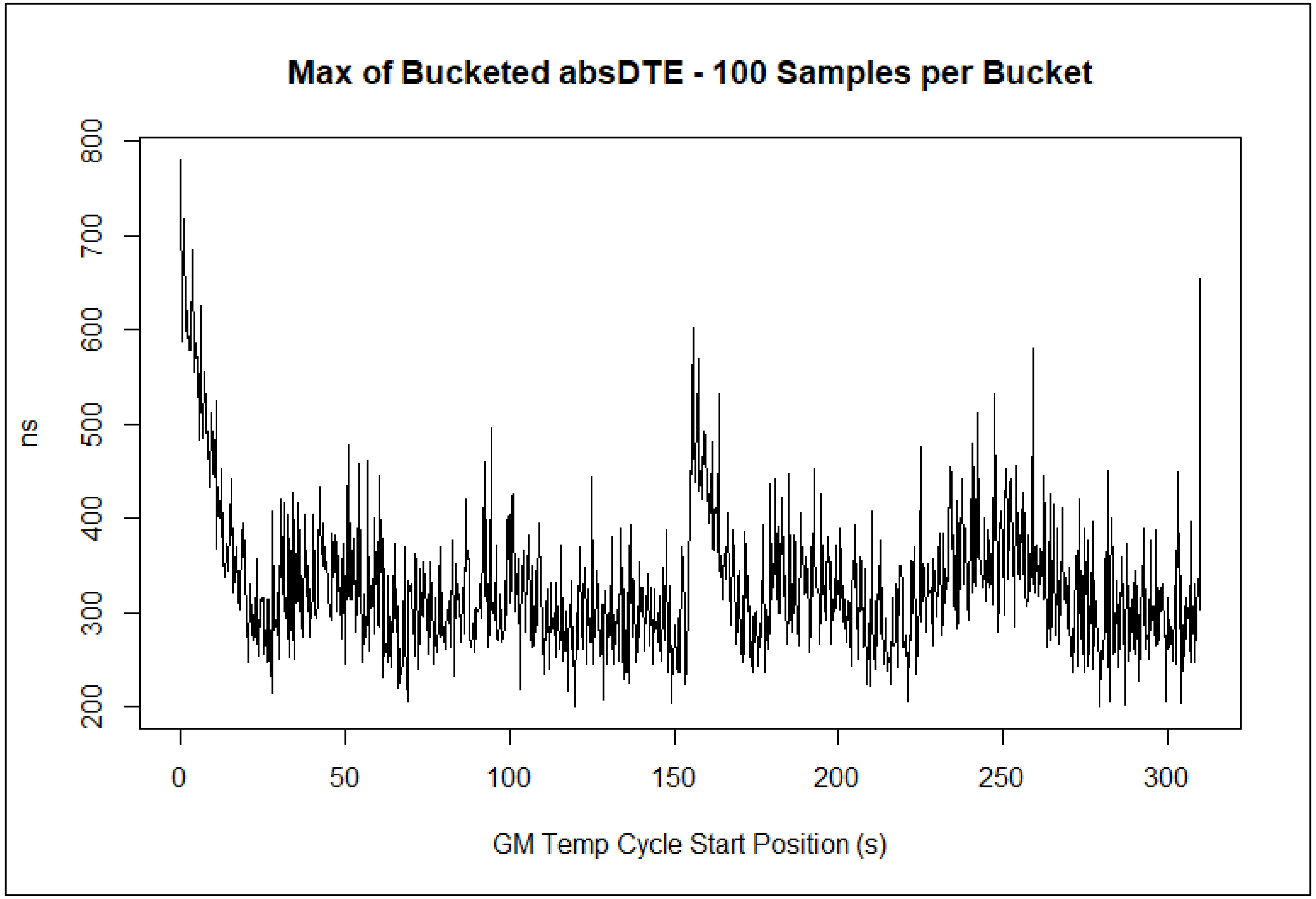
- When the drift tracking and compensation algorithm is working well, larger mNRRsmoothingNA values lead to lower time sync error.
  - Diminishing returns for drift tracking accuracy beyond mNRRcompNAP 8
  - For mNRRcomp8, values of mNRRsmoothing 8 or 6 appear optimal (at least for the temperature ramp we are using)
- When the drift tracking and compensation algorithm isn't working well, larger mNRRsmoothingNA lead to higher time sync error.
- Question: is there a lower limit for mNRRsmoothingNA below which Timestamp Errors dominate?
  - Run additional simulations to investigate.

Quarter-Sinusoidal; No NRR/RR Tracking; mNRRsmoothingNA 3; 125 s Temp Ramp; GM Scale 0.5



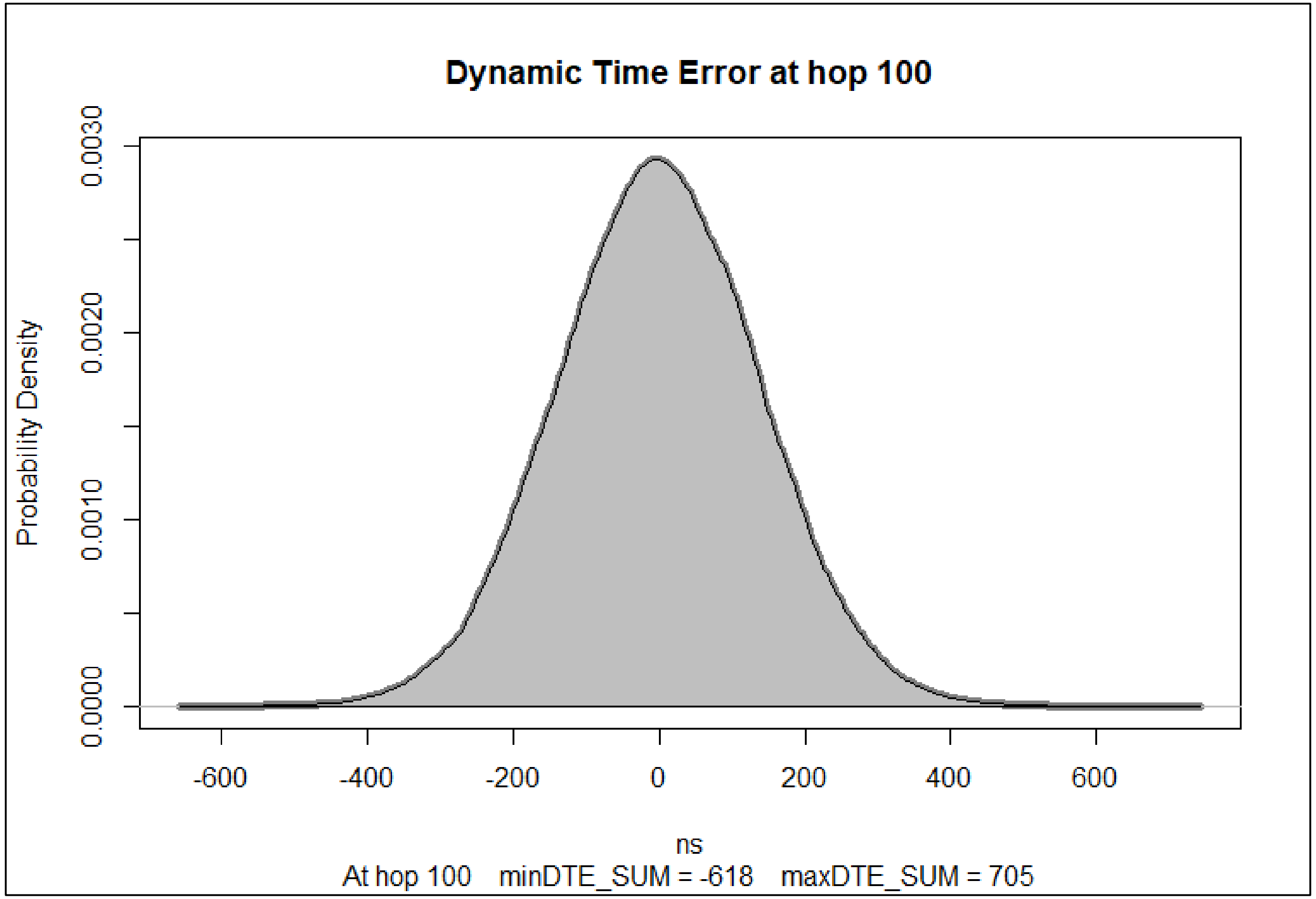
- Min/Max ±750 ns, an improvement of approx. 300 ns.
  - With mNRRsmoothingNA 4 was ±1050 ns

Quarter-Sinusoidal; No NRR/RR Tracking; mNRRsmoothingNA 3; 125 s Temp Ramp; GM Scale 0.5



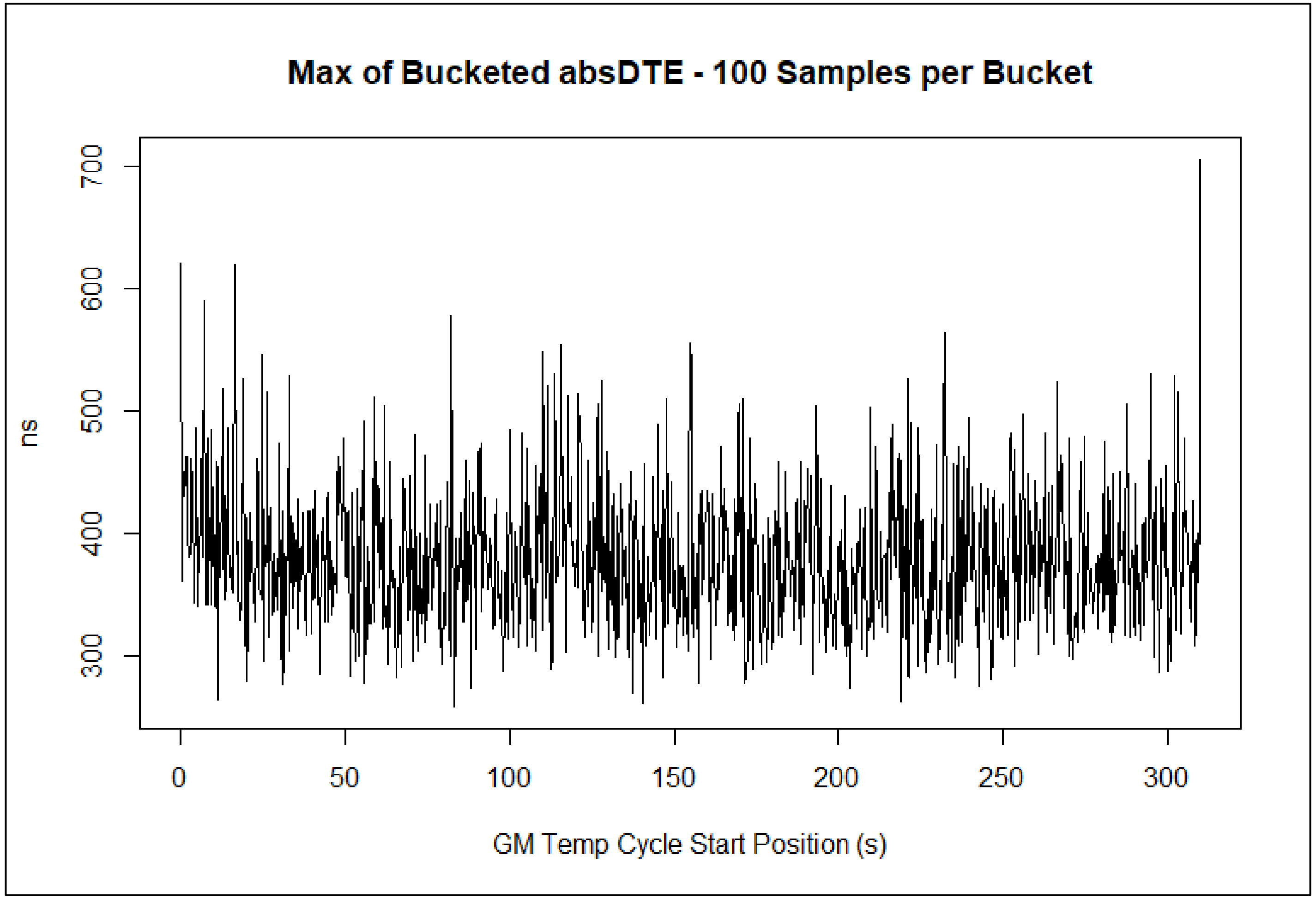
- Most of the noise curve appears to be 100 to 150ns lower.

Quarter-Sinusoidal; No NRR/RR Tracking; mNRRsmoothingNA 2; 125 s Temp Ramp; GM Scale 0.5



- Min/Max -620 to + 700 ns (approx.), an improvement of approx. 90 ns.
  - With mNRRsmoothingNA 3 was ±750 ns

Quarter-Sinusoidal; No NRR/RR Tracking; mNRRsmoothingNA 2; 125 s Temp Ramp; GM Scale 0.5

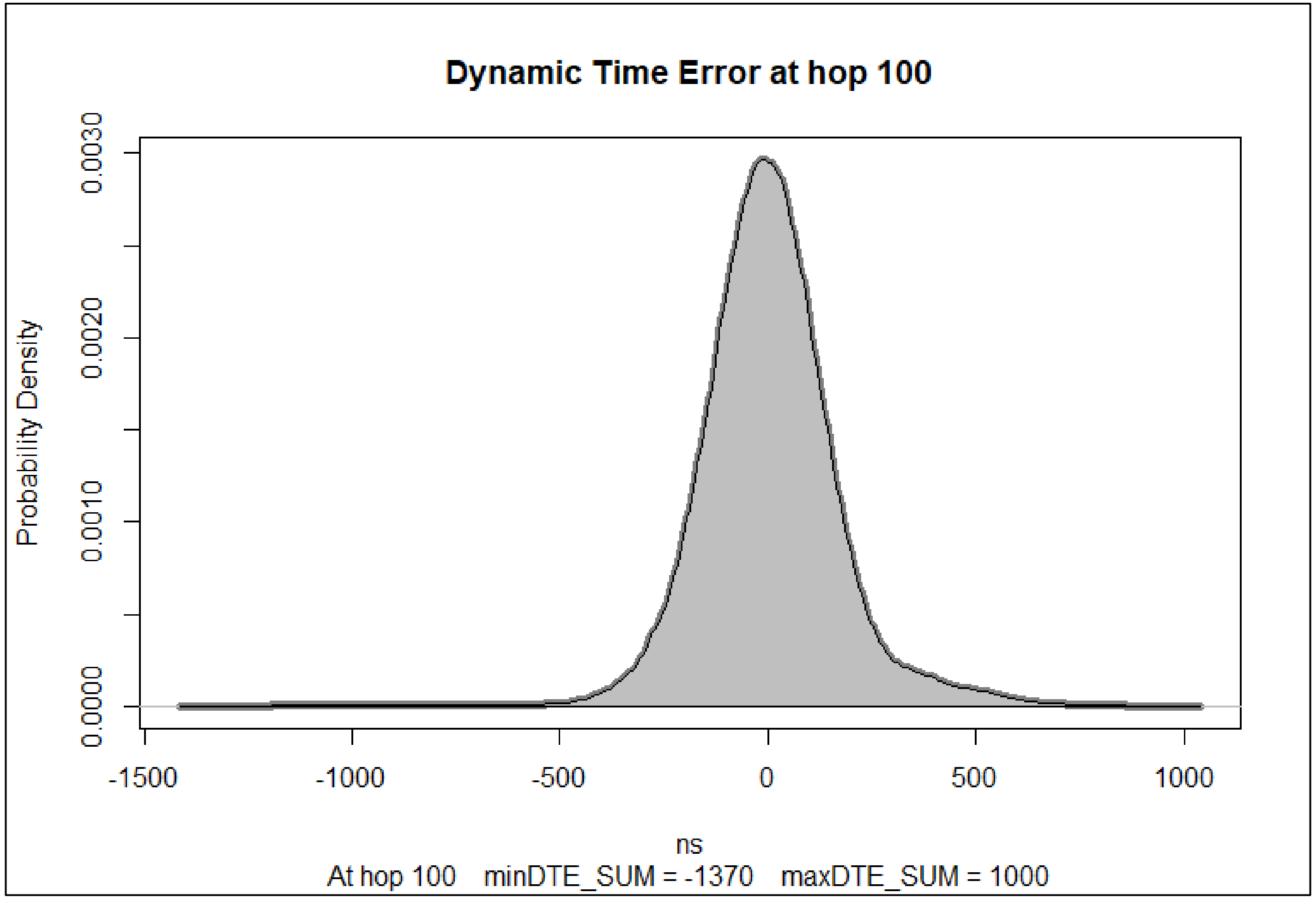


- No correlation with GM Temp Cycle Start Position, which indicates that Timestamp error is dominating.

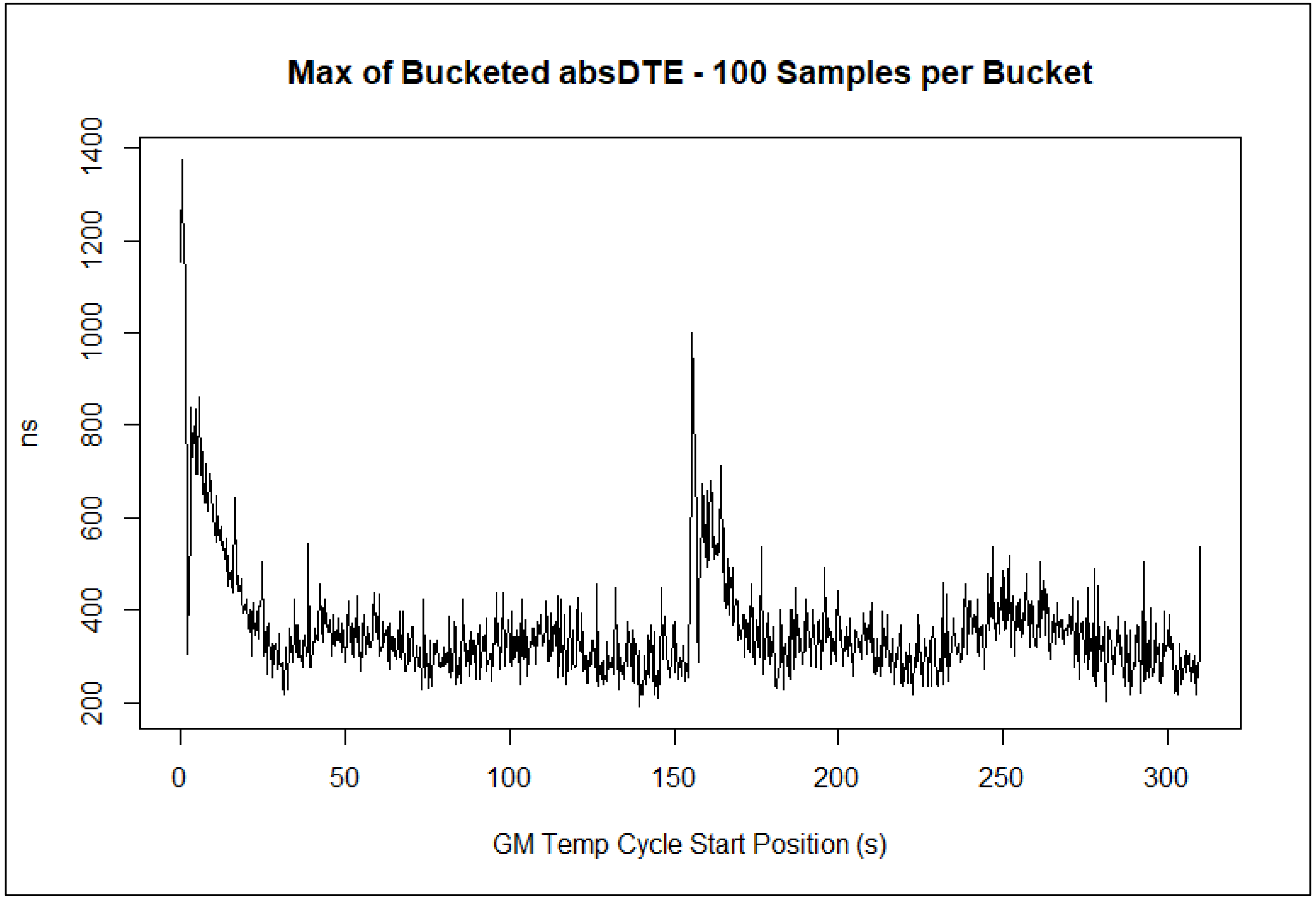
Question: What happens if you add Drift Tracking & Error Compensation Back In?

- Run simluations with…
  - Quarter-Sinusoidal; mNRRcompNAP 8; mNRRsmoothingNA 3; 125 s Temp Ramp; GM Scale 0.5
  - Quarter-Sinusoidal; mNRRcompNAP 8; mNRRsmoothingNA 2; 125 s Temp Ramp; GM Scale 0.5

Quarter-Sinusoidal; mNRRcompNAP 8; mNRRsmoothingNA 3; 125 s Temp Ramp; GM Scale 0.5



Quarter-Sinusoidal; mNRRcompNAP 8; mNRRsmoothingNA 3; 125 s Temp Ramp; GM Scale 0.5



Summary
& Proposed Configuration for
Time Series Simulations

Summary

- For Half-Sinusoidal temperature ramp (↕125 s) optimal values are…
  - mNRRcompNAP 8
  - mNRRsmoothingNA 8 (or 6, but 8 allows reuse of calculations)
- For increased robustness against any discontinuities…
  - mNRRsmoothingNA 4

  …won't incur much of a penalty when there are no discontinuities
- NRR/RR drift tracking and error compensation buys significant benefits
  - From 200 ns cTE error budget to 400+ ns cTE error budget
- Note: this is all "unfiltered" dTE. Time Series simulation required to determine "filtered" dTE.

Recommended Time Series Simulation Configurations

- Based on "default" values in Backup (see following slides)
- Half-Sinusoidal Temp Ramp
  - Min Temp -40°C; Max Temp +85°C; Ramp period 95 s; Hold time at Min and Max temp 30 s [Temp Cycle Period 250 s]
  - Usual ppm offset vs temperature curve for non-GM instances
  - Usual ppm offset vs temperature curve but with (ppm offset / 2) for GM
  - Each node is assigned a random starting position along the temperature cycle
    - Uniform distribution from 0 s to 250 s
- Three mNRR variants; 1300 s simulation time & discard first 50 s; 300 replications of each (if possible in reasonable time)
  - mNRRcompNAP 8; mNRRsmoothingNA 4
  - mNRRcompNAP 8; mNRRsmoothingNA 8
  - No drift tracking and compensation; mNRRsmoothingNA 4

Other Parameters and Values – 1

- Timestamp Granularity Error 8 ns (based on 125 MHz clock)
  - Truncate to next lowest multiple of 8 ns
  - For generation of preciseOriginTimestamp at the GM, add 4ns (but not at other nodes)
- Dynamic Timestamp Error ±6 ns
  - Uniform distribution
- Pdelay Interval (Pdelay_Req / _Resp is only used to calculate meanLinkDelay and not NRR)
  - Nominal nterval between two Pdelay_Req messages 125 ms
  - Actual interval between two Pdelay_Req messages:
    - Uniform distribution between (nominal x PDImin) and (nominal x PDImax)
  - PDImin = 0.9
  - PDImax = 1.3

Other Parameters and Values – 2

- Sync Interval @ GM (used to calculate NRR)
  - Uniform distribution between 119 ms and 131 ms (nominal 125 ms)
- Residence Time
  - Normal Distribution: Mean 5 ms; Standard Deviation 1.8 ms; Truncated at 1 ms and 15 ms
    - Truncated values are converted to 1 ms or 15 ms respectively
- Pdelay Turnaround Time
  - Normal Distribution: Mean 10 ms; Standard Deviation 1.8 ms; Truncated at 1 ms and 15 ms
    - Truncated values are converted to 1 ms or 15 ms respectively

Other Parameters and Values – 3

- Link Delay (actual link delay being modelled)
  - Uniform distribution between 5 ns and 500 ns
- MeanLinkDelay Averaging
  - IIR filter that uses 99/100 of previous “average” + 1/100 of most recent measurement
- In-Sync Threshold
  - Out of sync if 3 times in a row…
    - RX (Precise Origin Timestamp + Correction Field) – Current Grandmaster Time Estimate is > 1µs or < -1µs
  - Back in sync if 3 times in a row…
    - RX (Precise Origin Timestamp + Correction Field) – Current Grandmaster Time Estimate is < 1µs and > -1µs

Other Parameters and Values – 4

- ClockTarget Filter
  - K_pK_o = 11 rad/s
  - K_iK_o = 65 (rad/s)^2
  - H_p = 2.1985 dB
  - f_{3dB} = 2.6 Hz
- Record filtered values & unfiltered values

Save Information for Separate Investigation of Control Loop

- At each arrival of a Sync message at 64th Node and 100th Node
  - Simulation time of Sync message arrival
  - GM Time
  - precisionOriginTimestamp + correctionField
  - rateRatio (incoming rateRatio + mNRRc)
  - rateRatioDrift (incoming rateRatioDrift + mNRRdrift)
- Once, at the start of the simulation
  - Initial temperature cycle offsets for Nodes 64 and 100

Investigation of Timestamp Granularity Error Offset

- For message egress at GM and message ingress at Node 1…
- Record distribution of amount of truncation for each Timestamp Granularity Error
  - Output: probability distribution histogram with bin size of 0.1 ns
  - Separate distribution histogram for egress at GM and ingress at Node 1

Thank you!

Backup

Default Configuration

```
hops <- 100 # Minimum 1 hop
runs <- 100000
#
# Input Errors, Parameters & Correction Factors
driftType <- 4 # 1 = DO NOT USE - Historical - Uniform Probability Distribution between MIN & MAX ppm/s
               # 2 = Probability Based on Linear Temp Ramp
               # 3 = Probability Based on Half-Sinusoidal Temp Ramp
               # 4 = Probability Based on Quarter-Sinusoidal Temp Ramp
# Clock Drift Probability from Temp Curve & XO Offset/Temp Relationship
tempMax <- +85 # degC - Maximum temperature
tempMin <- -40 # degC - Minimum temperature
tempRampRate <- 1 # degC/s - Drift Rate for Linear Temp Ramp
tempRampPeriod <- 125 # s - Drift Period for Sinusoidal & Half-Sinusoidal Temp Ramps
tempHold <- 30 # s - Hold Period at MIN and MAX temps before next temp ramp down or up
GMscale <- 1 # Ratio of GM stability vs. standard XO. 1 is same. 0 is perfectly stable.
nonGMscale <- 1 # Ratio of non-GM (and non-ES) node stability vs. standard XO. 1 is same. 0 is perfectly stable.
```

Default Configuration

TSGEtx <- 4 # +/- ns - Error due to Timestamp Granularity on TX

TSGErx <- 4 # +/- ns - Error due to Timestamp Granularity on RX

DTSEtx <- 6 # +/- ns - Dynamic Timestamp Error on TX

DTSErx <- 6 # +/- ns - Dynamic Timestamp Error on RX

pDelayInterval <- 125 # ms - Nominal Interval between two pDelay measurements

PDImax <- 1.3 # Max factor for Tpdelay2pdelay (uniform linear distribution max of pDelayInterval x PDImax)

PDImin <- 0.9 # Min factor for Tpdelay2pdelay (uniform linear distribution min of pDelayInterval x PDImin)

syncInterval <- 125 # ms - Nominal Interval between two Sync messages

SImode <- 3 # Mode for generating Tsync2sync *HARD CODED to MODE 3*

    # 1 = Gamma Distribution, defaulting to 90% of Tsync2sync falling within 10% of the nominal syncInterval. Truncated at SImax (higher values above are reduced to SImax)

    #   No truncation of low values

    # 2 = Gamma Distribution, defaulting to 90% of Tsync2sync falling within 10% of the nominal syncInterval. Truncated at SImax (higher values are reduced to SImax)

    #   Truncated at SImin (lower values are increased to SImin)

    # 3 = Uniform, linear distribution between syncInterval x SImin and syncInterval x SImax

Default Configuration

```
SIscale <- 1 # Scaling factor for Mode 1 & 2 Tsync2sync vs regular distribution.
        # Scaling factor of 3 would mean 90% of Tsync2sync falling within 30% of the nominal syncInterval
SImax <- 1.048    # For mode 1 & 2, Max truncation factor (e.g. 2x syncInterval) limit for Tsync2sync; higher values reduced to SImax
            # For mode 3, upper limit of uniform linear distribution
SImin <- 0.952    # For mode 1 & 2, Min truncation factor (e.g. 0.5 x syncInterval) limit for Tsync2sync; higher values reduced to SImin
            # For mode 3, lower limit of uniform linear distribution
pDelayTurnaround <- 15 # ms - TpdelayTurnaround maximum; higher values truncated
pathDelayMin <- 5 # ns - 1m cable = 5ns path delay
pathDelayMax <- 500 # ns - 100m cable = 500ns path delay
PDTmin <- 1 # TpdelayTurnaround minimum; lower values truncated
PDTmean <- 10 # TpdelayTurnaround mean
PDTsd <- 1.8 # TpdelayTurnaround sigma; 3.4ppm will fall outside 6-sigma either side of the mean
residenceTime <- 15 # ms - TresidenceTime maximum; higher values truncated
RTmin <- 1 # TresidenceTime minimum; lower values truncated
RTmean <- 5 # TresidenceTime mean
RTsd <- 1.8 # TresidenceTime sigma; 3.4ppm will fall outside 6-sigma either side of the mean
```

Default Configuration

```
mLinkDelayAverage <- 50 # Number of Path Delay calculations, from Pdelay_Req & _Resp messages
                        # that are averaged to generate mLinkDelay
mNRRsmoothingNA <- 4 # Whole Number >=1 - Combined N & A value for "smoothing" calculated mNRR (mNRRc)
                     # Calculate mNRR using timestamps from Nth Sync message in the past
                     # Then take average of previous A mNRRcalculations.
mNRRcompNAP <- 4 # Whole Number >=1
                 # For NRR drift rate error correction calculations, take two measurements, mNRRa and mNRRb.
                 # Both use timestamps from Nth Sync message in the past, then take average of previous A calculations.
                 # Calculation mNRRb starts P calculations in the past from mNRRa, where P = mNRRcompNAP * 2.
                 # If 0, there is no NRR drift rate error correction.
```