Performance Heterogeneity in High Performance GPUs

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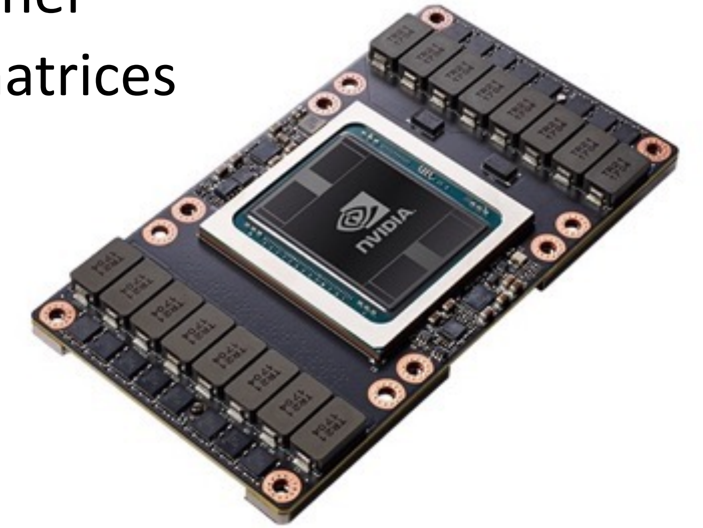
Previous Meetings: Setup

Power bound benchmark [3]

- cuBLAS SGEMM kernel
- Input: 25k by 25k matrices of 32bit floats

Measurements

- NVIDIA's nvprof profiler: Performance, Power, Temperature, Frequency
- Median values of 100 repetitions/run



NVIDIA V100-SXM2

- Set to max Frequency (1530 MHz)
- Set to TDP Power limit (300 W)

[3] Coplin, J., & Burtscher, M. Energy, power, and performance characterization of GPGPU benchmark programs. *In Proceedings - 2016 IEEE 30th International Parallel and Distributed Processing Symposium, IPDPS* 2016 (pp. 1190–1199). (2016). https://doi.org/10.1109/IPDPSW.2016.164

Study Locations

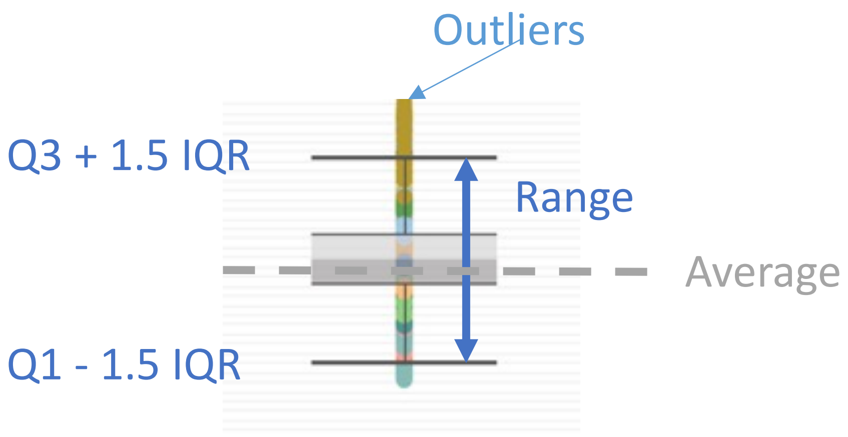
- CloudLab
  - 4 V100 SXM2 GPUs / node
  - Air cooled
  - 10’s of GPUs
- TACC’s Longhorn cluster
  - 4 V100 SXM2 GPUs / node
  - Air cooled + mineral cooled
  - 100’s of GPUs
- SNL’s Vortex cluster
  - 4 V100-SXM2 GPUs / node (Power9)
  - Water cooled
  - 100’s of GPUs
- ORNL’s Summit cluster
  - 6 V100-SXM2 GPUs / node
  - Water cooled
  - 10000’s of GPUs

Let’s define variation

$$\text{Relative range} = \frac{\text{Range}}{\text{Average}} \times 100\ \%$$

Using Inter Quartile Range (IQR) based method

Captures 99.3 % of the Gaussian distribution



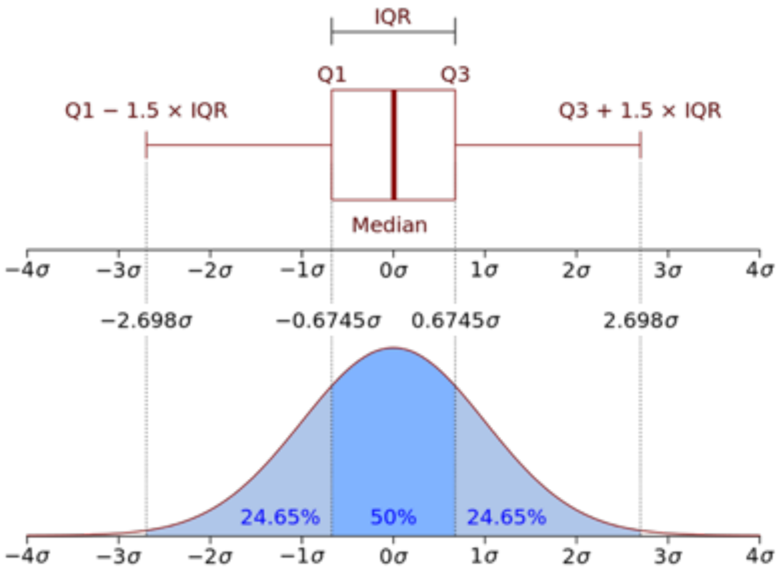
Outliers

Q3 + 1.5 IQR

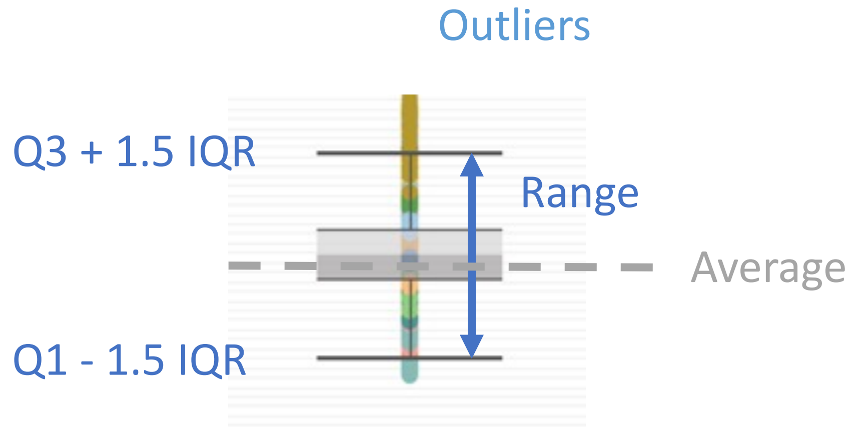
Range

Average

Q1 - 1.5 IQR



Last presentation (TACC)



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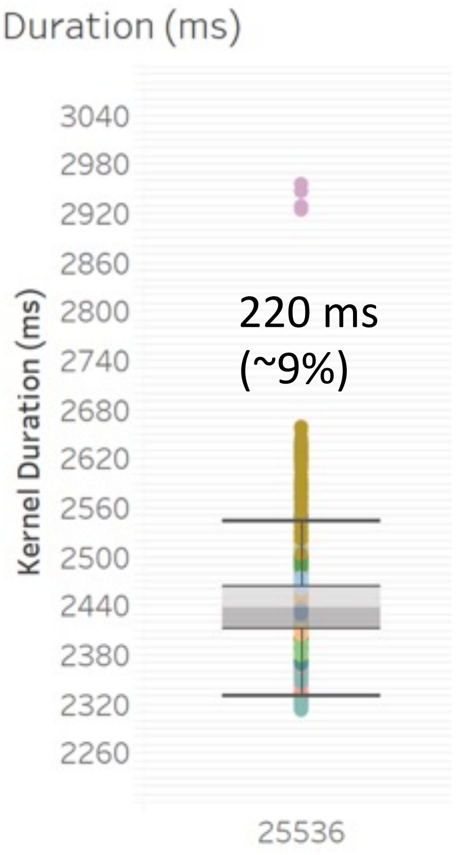
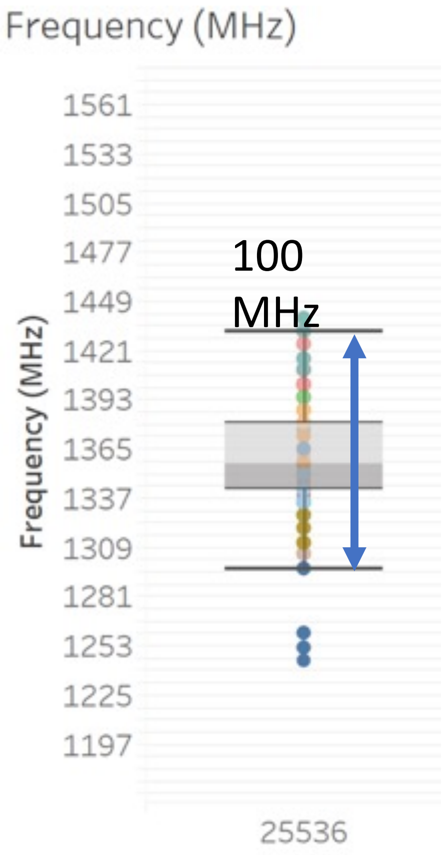
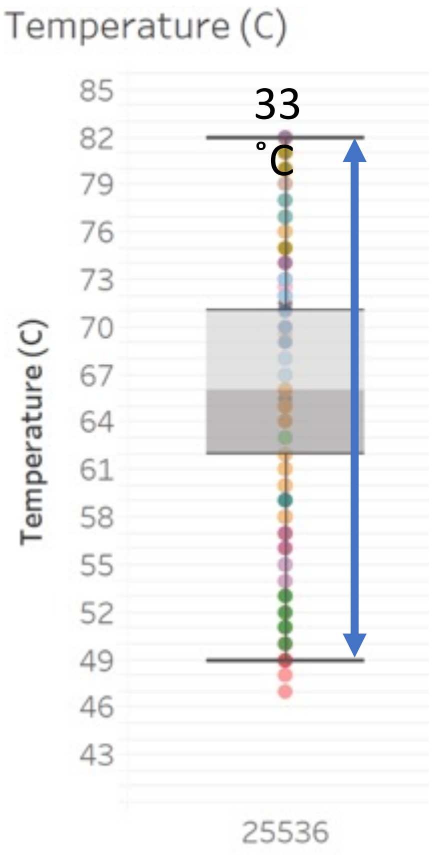


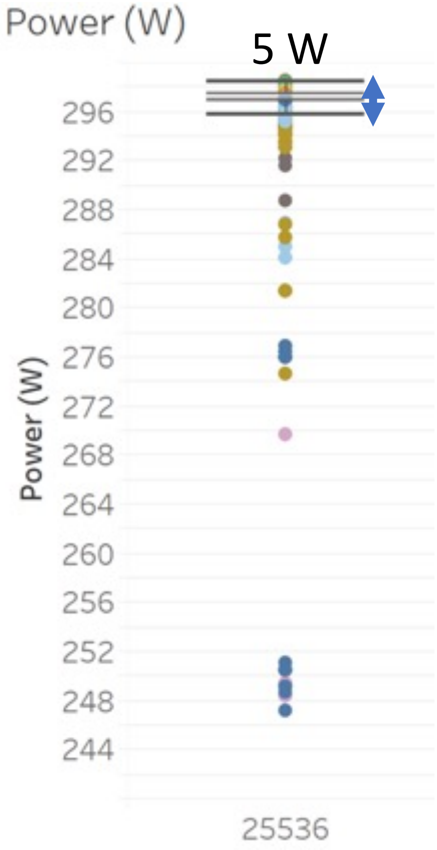
220 ms (~9%)



100 MHz



33 ˚C



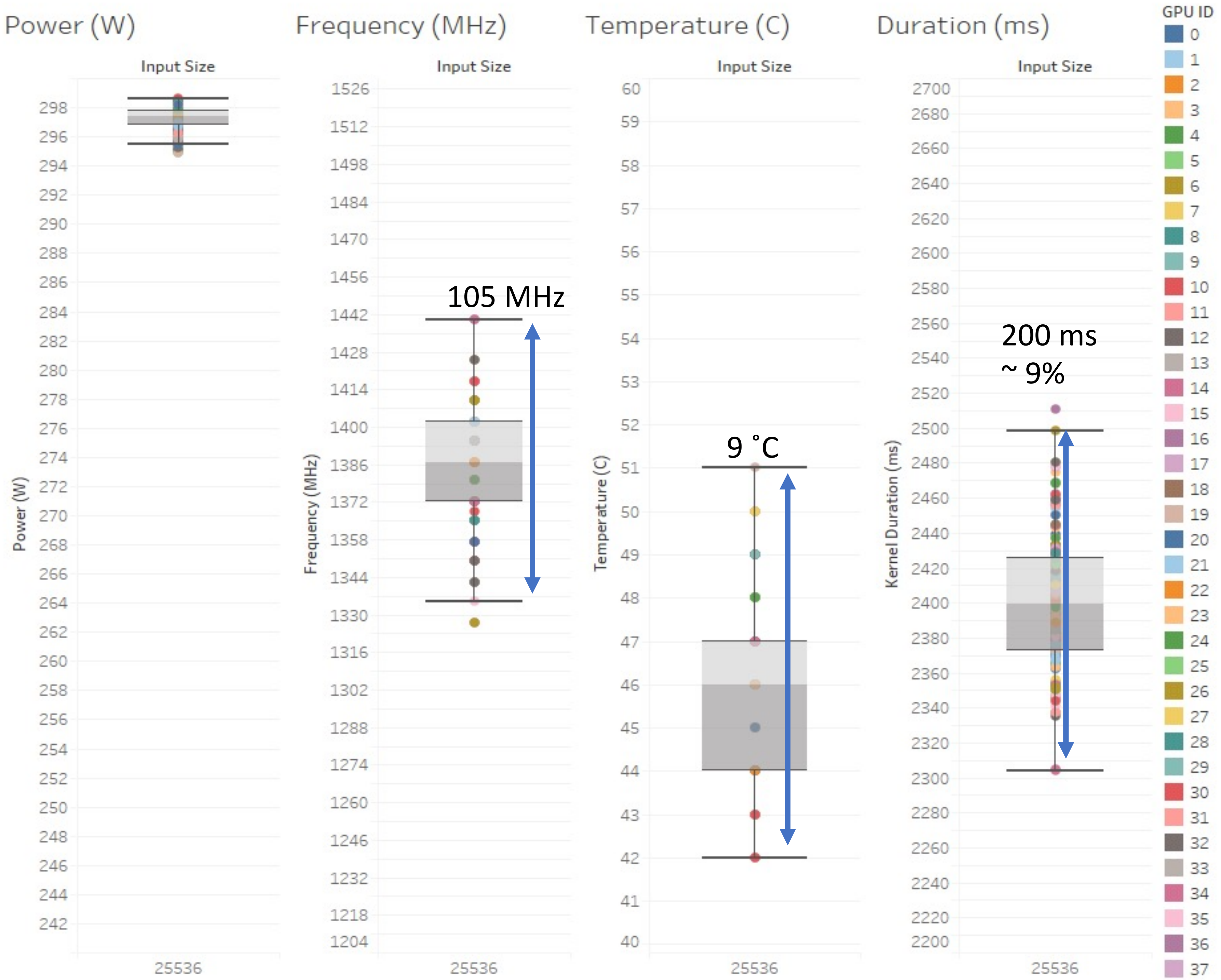
5 W

Last Presentation Vortex (SNL)

There is a 9% variation in kernel duration for the same workload

This variation is correlated to variation in operating frequency

Power management could be probable cause of this frequency variation

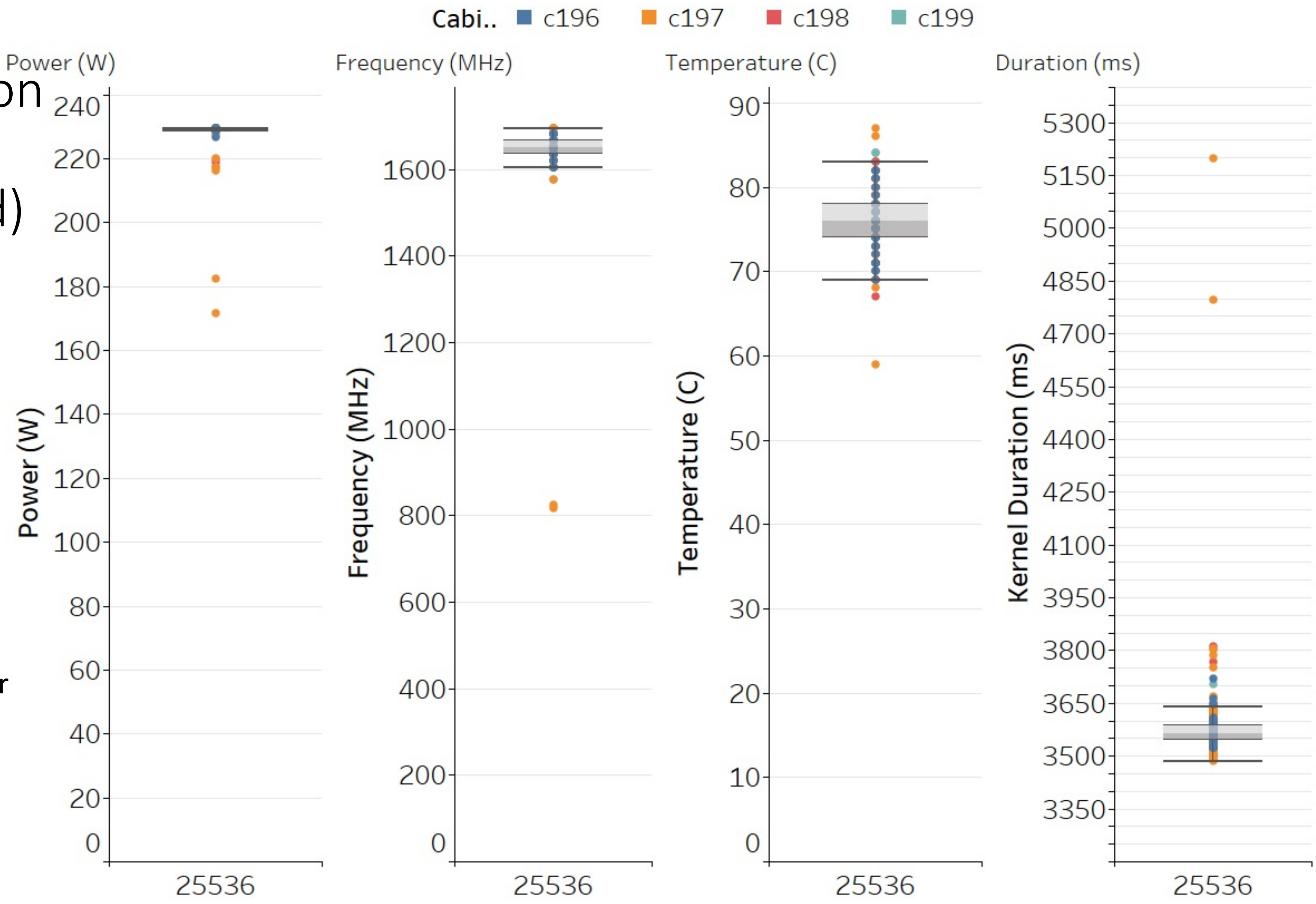


105 MHz

9 ˚C

200 ms
~ 9%

Last presentation Frontera (mineral cooled)



Power is around 235W (Quadro RTX)

Temperature band is narrower but also higher

Kernel duration is higher (Quadro RTX)

Frequency is higher (Quadro RTX?)

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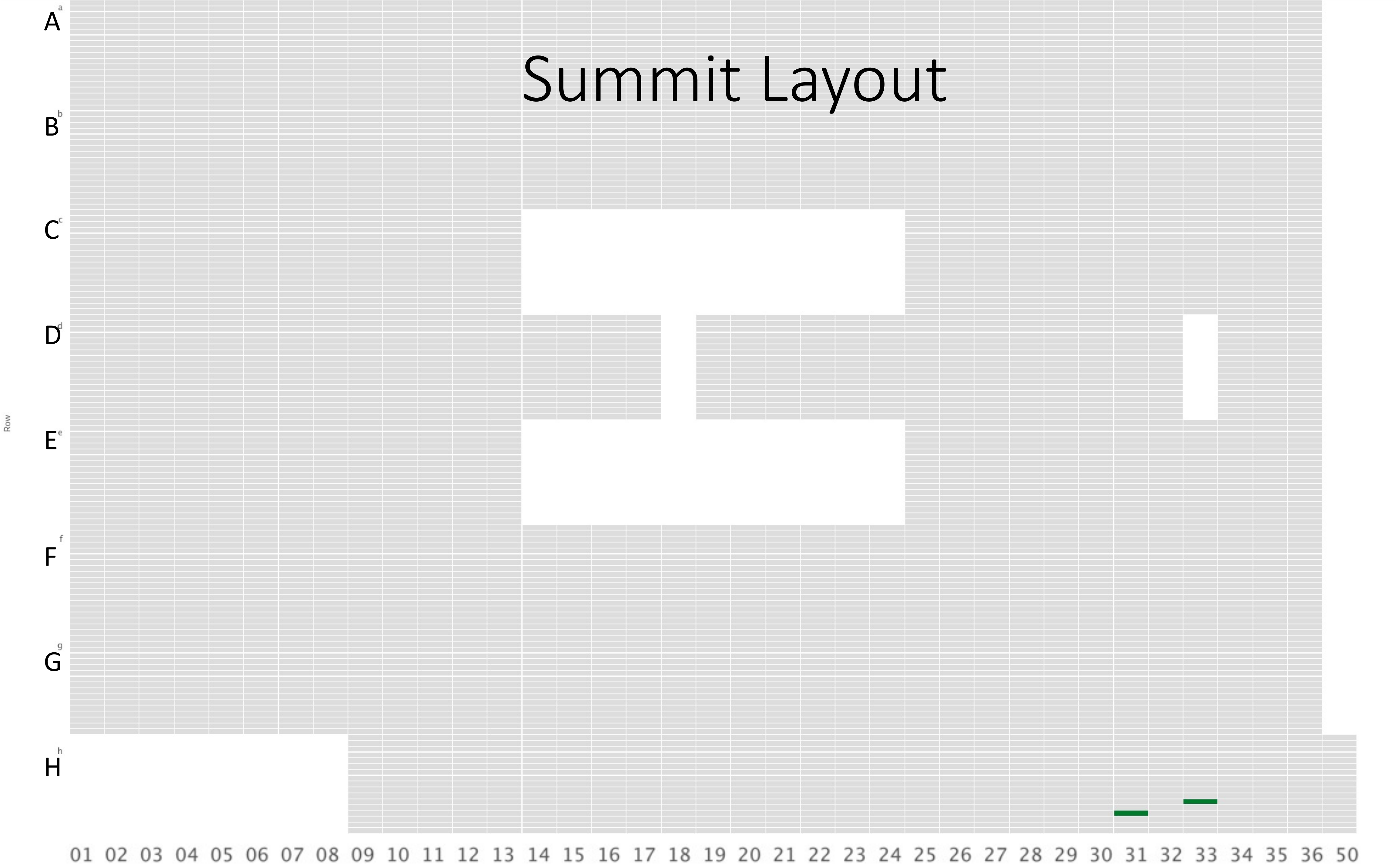
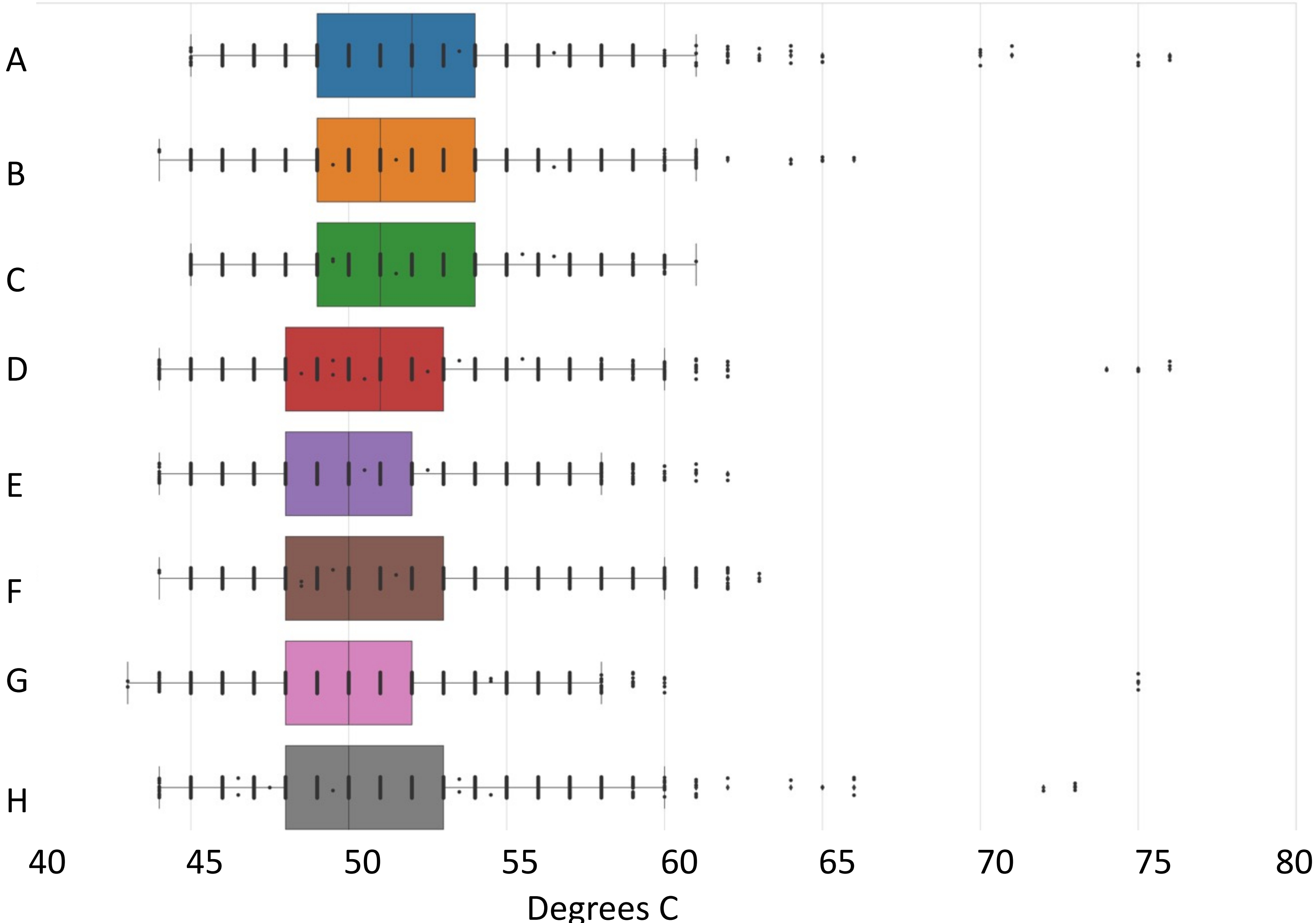
Summit Layout



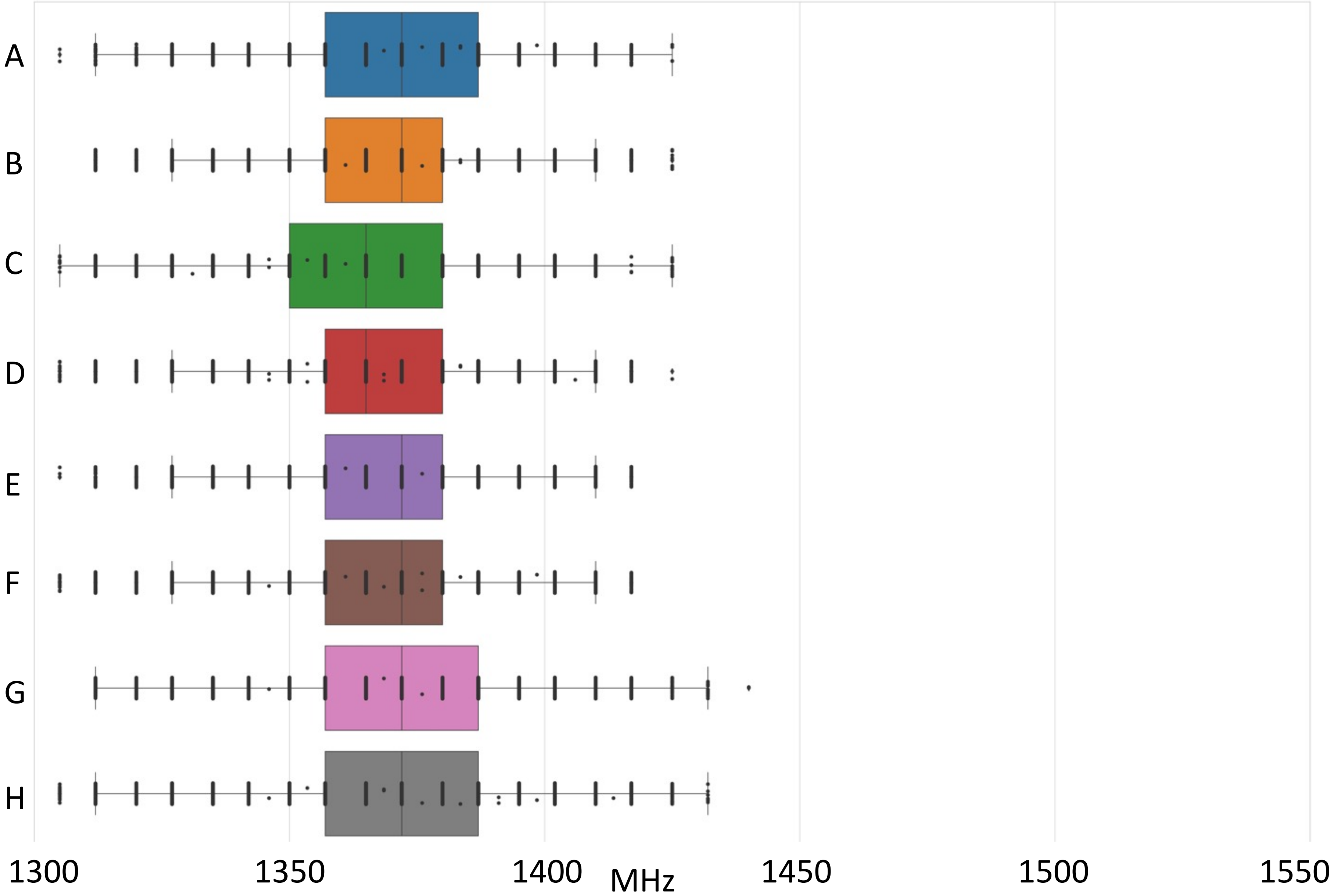
Summit Analysis (by row): Temperature

Takeaway:
Rows a, h see more outliers



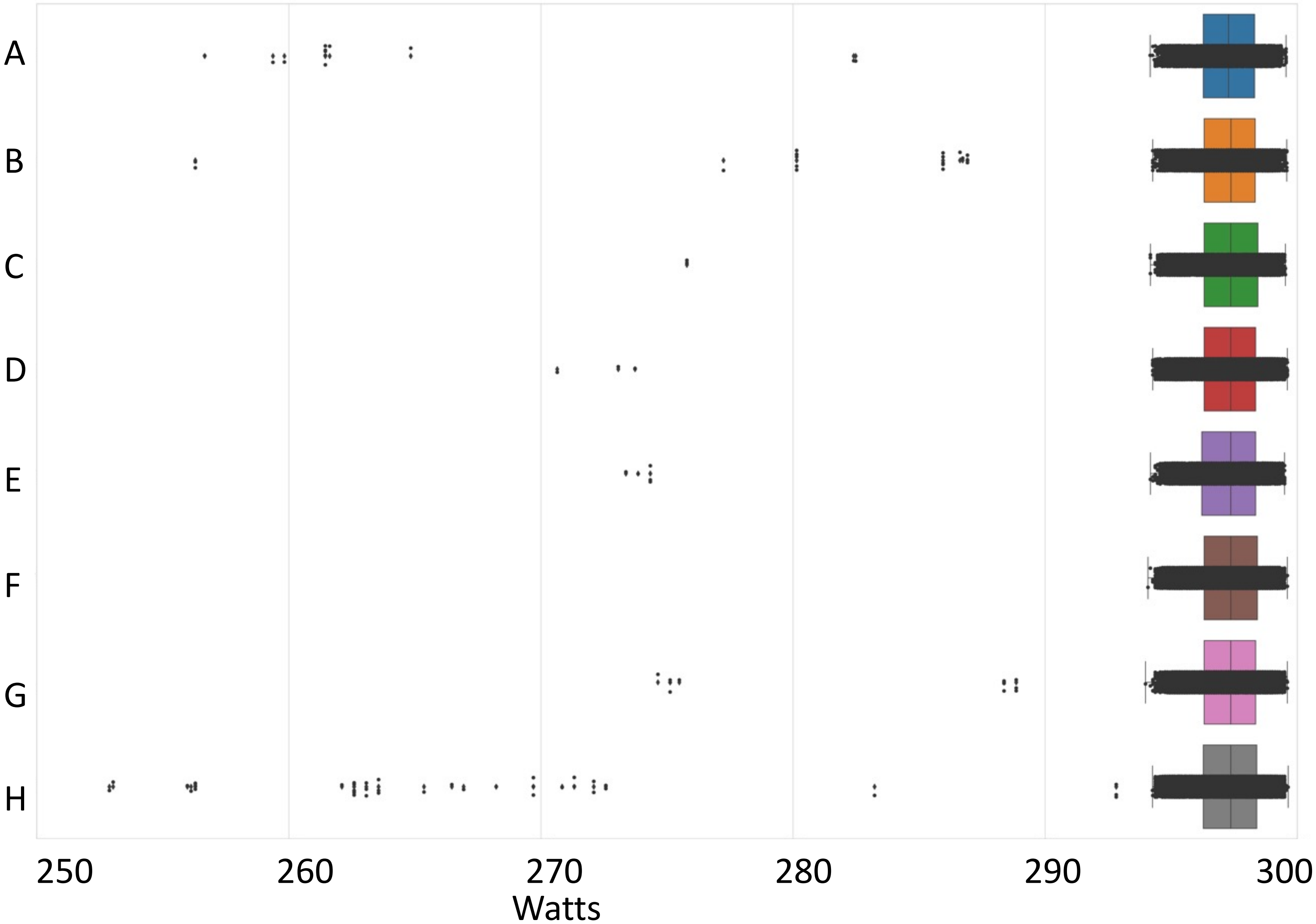
Summit Analysis (by row): Frequency

Takeaway: Outliers across many rows, but outlier range is not the same in each row



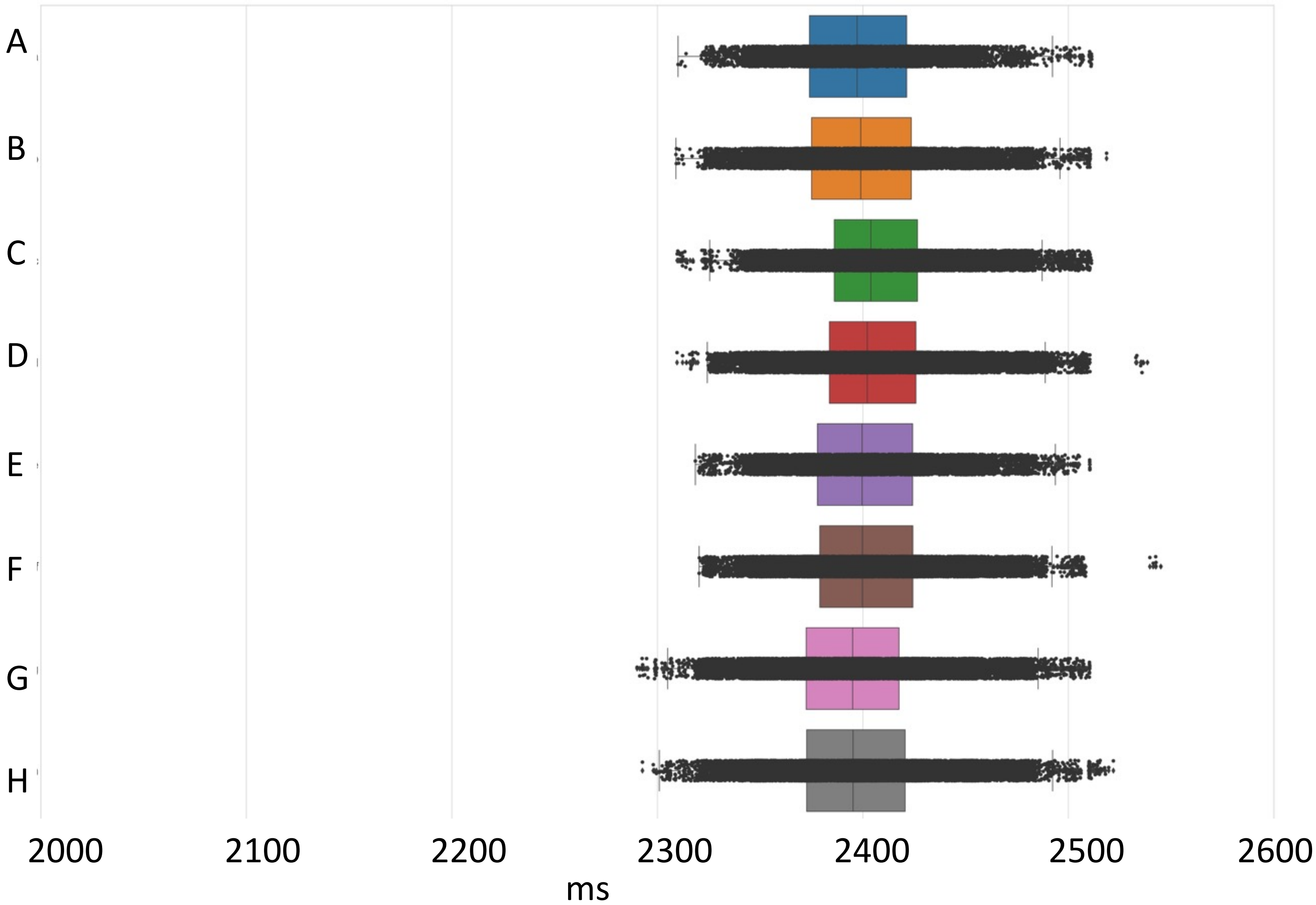
Summit Analysis (by row): Power

Takeaway: Similar to TACC some machines in row a, row h are at around 250W

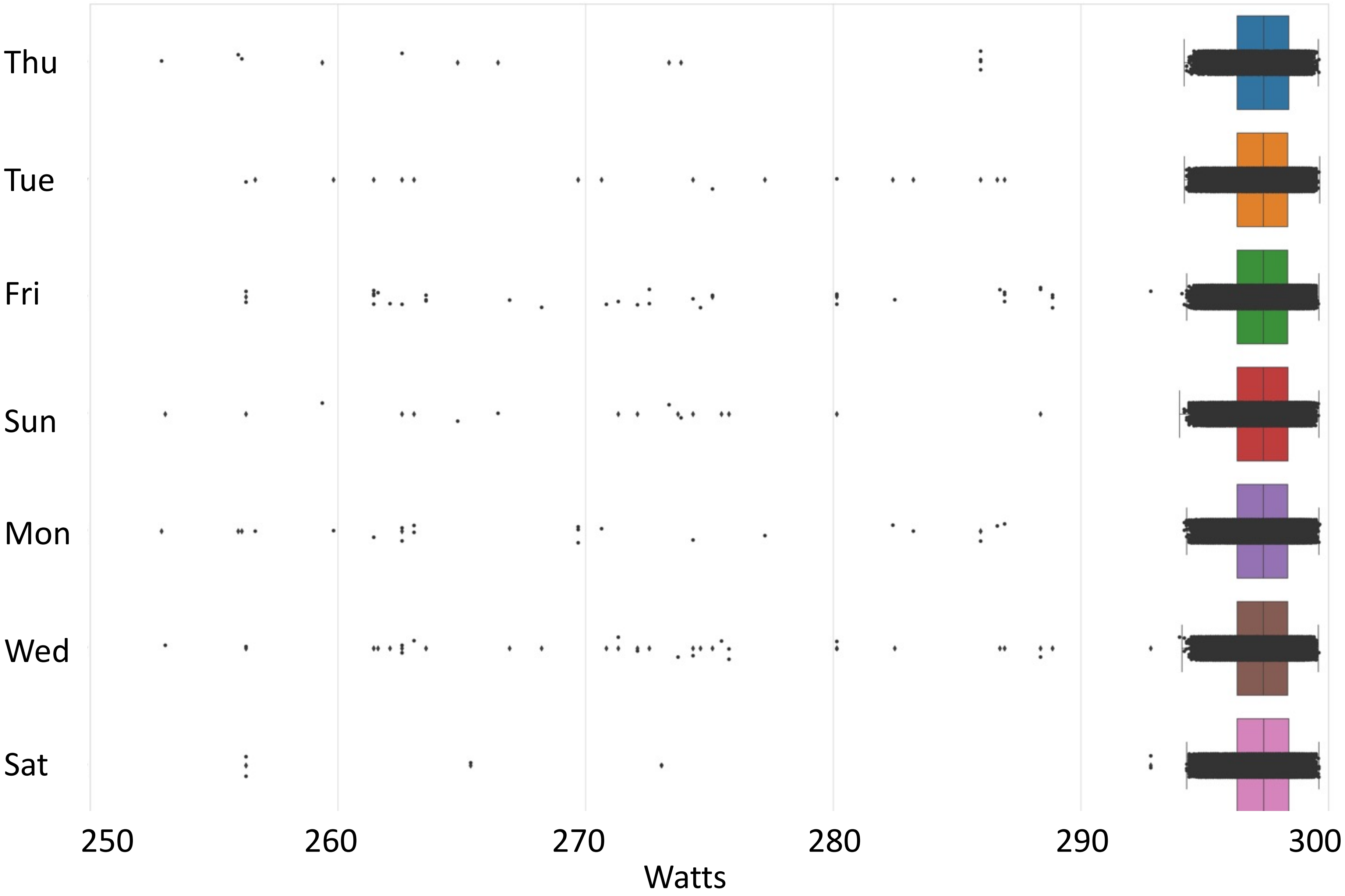


Summit Analysis (by row): Performance

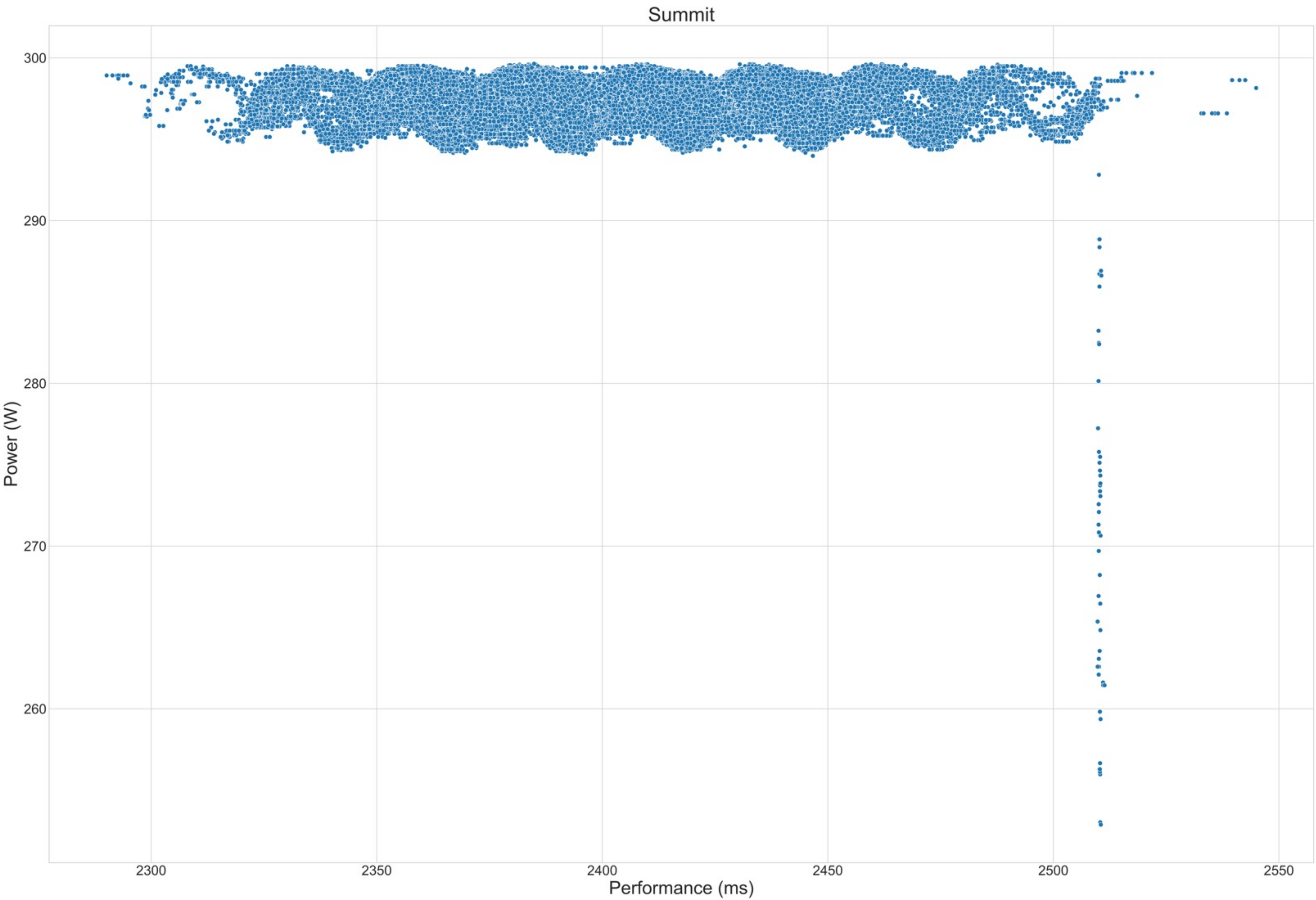
Takeaway: Performance outliers in row d and f are most severe



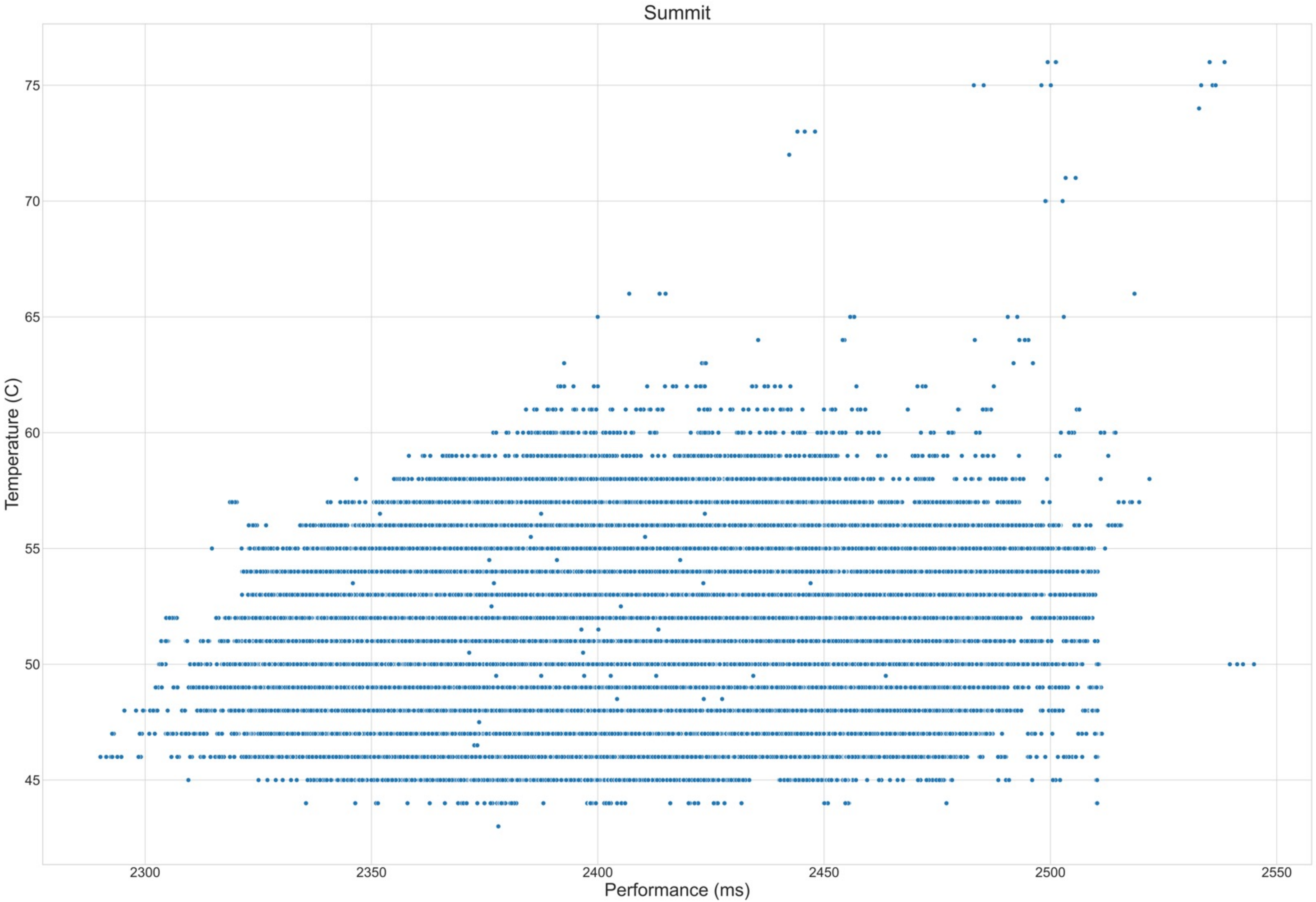
Summit Analysis: Day of the week (Power)



Perf vs Power



Perf vs Temperature



Work In Progress

- More diverse workloads (DOE Proxy Apps, Graph Analytics, ML):
  - Compute-Intensive: HACC, LAMMPS (EAM, ReactFF)
    - Irregular: Quicksilver
  - Memory-Intensive: AMR, LULESH, ML Training, QMCPack, SNAP, STREAM, XSBench
    - Irregular: Nekbone, Graph Analytics
    - Shared Memory Bound: Finite Element, Kripke
    - Latency Bound: Pennant (lots of pointer chasing)
  - Balanced: CoMD, LAMMPS (EAM), HPGMG