FAA CENTER OF EXCELLENCE FOR ALTERNATIVE JET FUELS & ENVIRONMENT

Validation of Low-Exposure Noise Modeling by Open-Source Data Management and Visualization Systems Integrated with AEDT

Project 53

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Introduction

- **Main Objective:**
  - Compare AEDT's noise predictions using advanced track and aircraft performance emulation (AEDT-AE) with the measured noise for the same flights (every flight, every day) and assess the differences in LAmax and SEL levels
  - Note: AEDT-AE (AEDT, BADA4, Altitude and Speed Controls) is not approved for regulatory use

- **Outcomes:**
  - Completed statistically-significant comparison of measured versus AEDT-AE predicted noise, at two locations, for every flight, over 12 months
  - Completed MONA system to archive, process, and query all measured and predicted data
  - Completed AEDT-AE processing system: creation of single flight studies, study execution, and extraction of study results, at any desired scale
  - MONA infrastructure paper published[1] and presented[1] at the 2021 OpenSky Symposium

Attempting to use **large data** in aviation environmental impact assessments

[1]*Jackson, D. C., Rindfleisch, T. C., Alonso, J. J., "A System for Measurement and Analysis of Aircraft Noise Impacts," Eng. Proc. 2021,13,6. https://doi.org/10.3390/engproc2021013006*

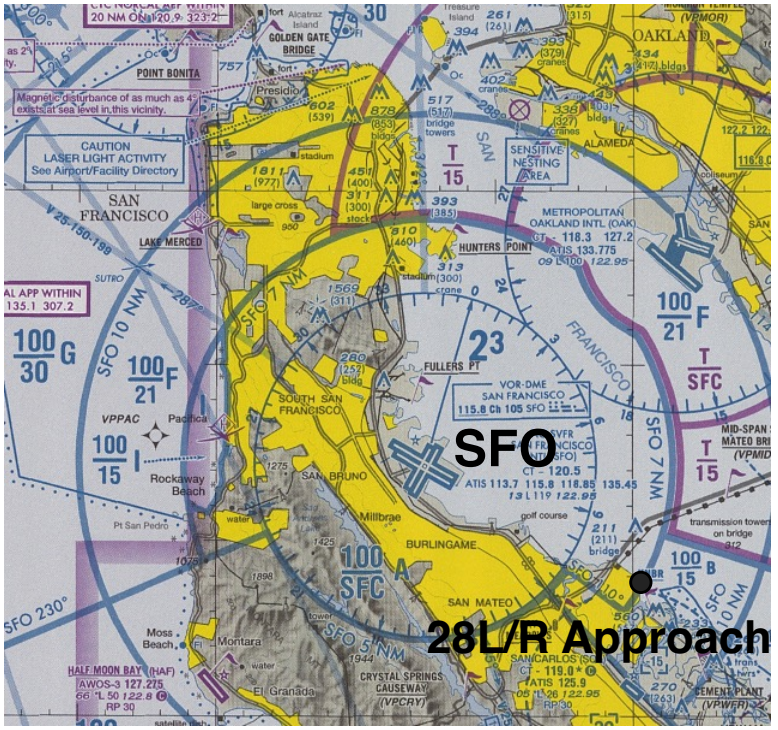
Most Recent Results

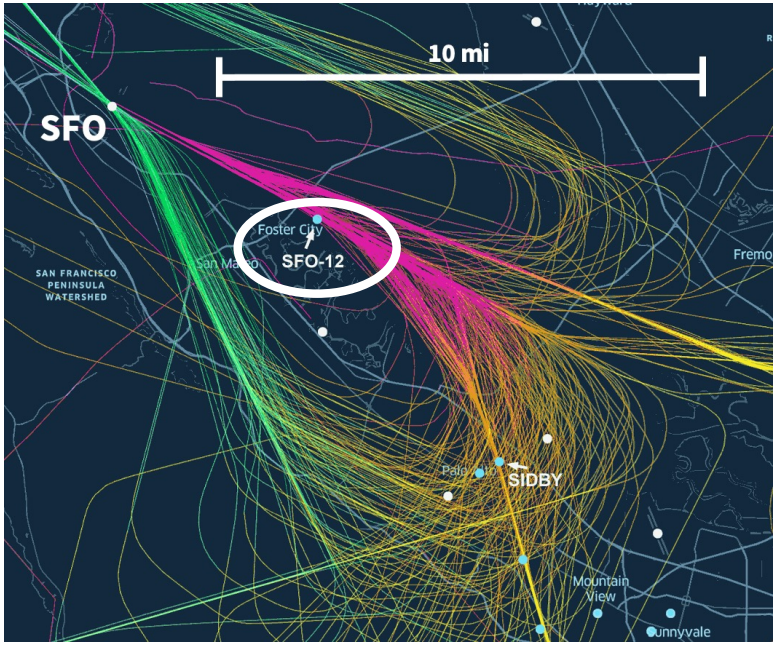
V&V of AEDT-AE Results in Low- and High-Noise Areas

- SFO arrivals into 28L/R over a 1-year period: July 1, 2021 – June 30, 2022
- Two sound-level monitor (SLMs) locations:
  - 28L/R Approach, ~61 dB DNL (SFO-NMT-12)
  - SIDBY Waypoint, ~46 dB DNL (Palo Alto, CA)
- Approximately 135,000 distinct flights, w/one AEDT-AE study per flight and with predictions for all receptors
- All aircraft types but, predominantly regional jets and single-aisle aircraft; GA flights excluded
- The 135K AEDT-AE studies were created automatically, took 5 days to compute, using 128 AEDT instances (VMs)
- ***Preliminary results, do not cite / share***

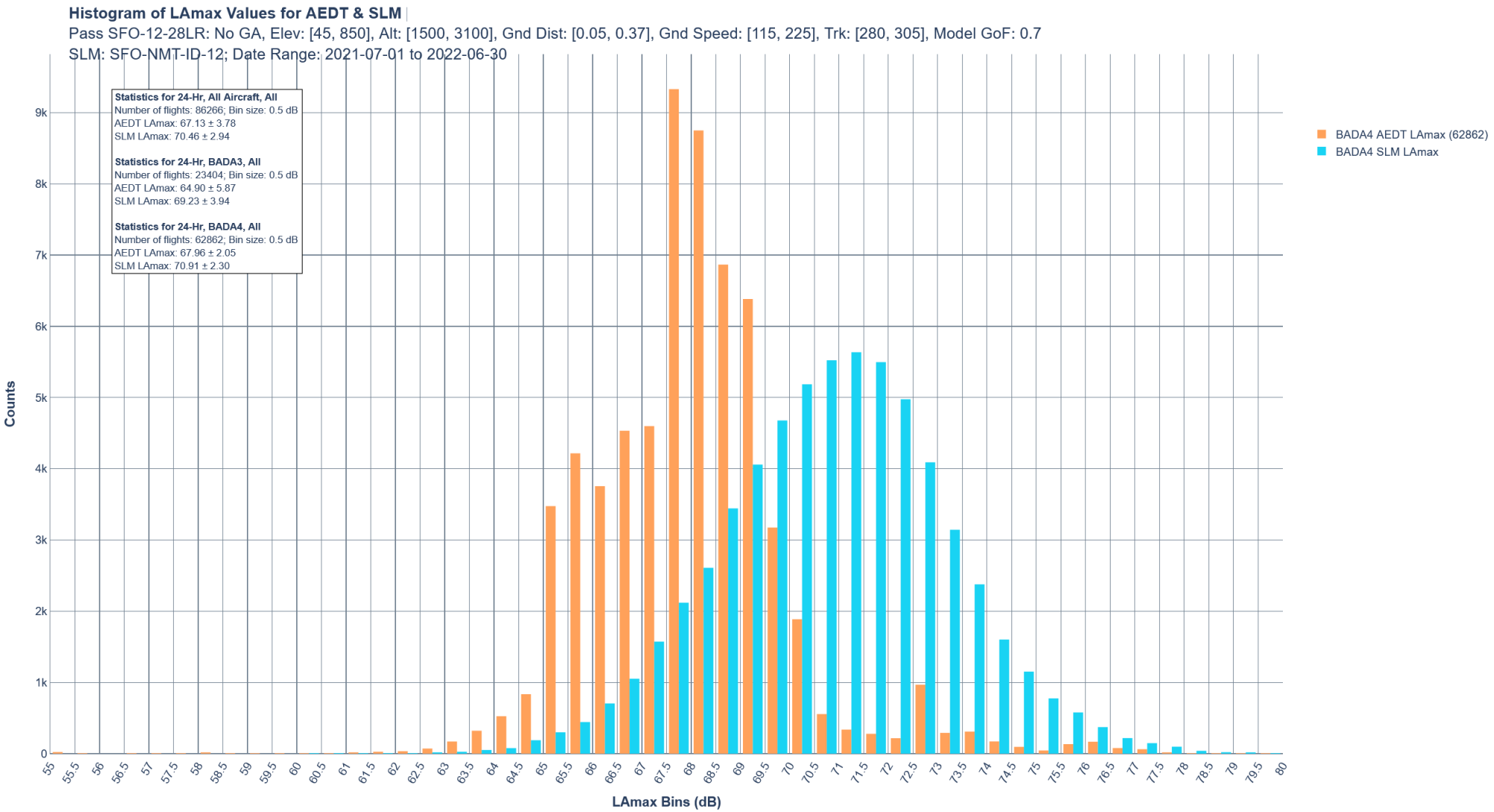
28L/R Approach (Foster City)

- Traffic into SFO 28L/R, July 1, 2021 – June 30, 2022
- Total number of flights: 134,178
- GA aircraft flights discarded: 4,057
- Noise events removed because of low Goodness of Fit (GoF): 34,870
- Flights skipped because of multiple aircraft at PCA/TCA: 5,568
- Flights discarded because of trajectory criteria (altitude, distance, heading, etc.): 3,417
- SFO / Envirosuite SLM
- **Remaining flights for 12-month period: 86,266**



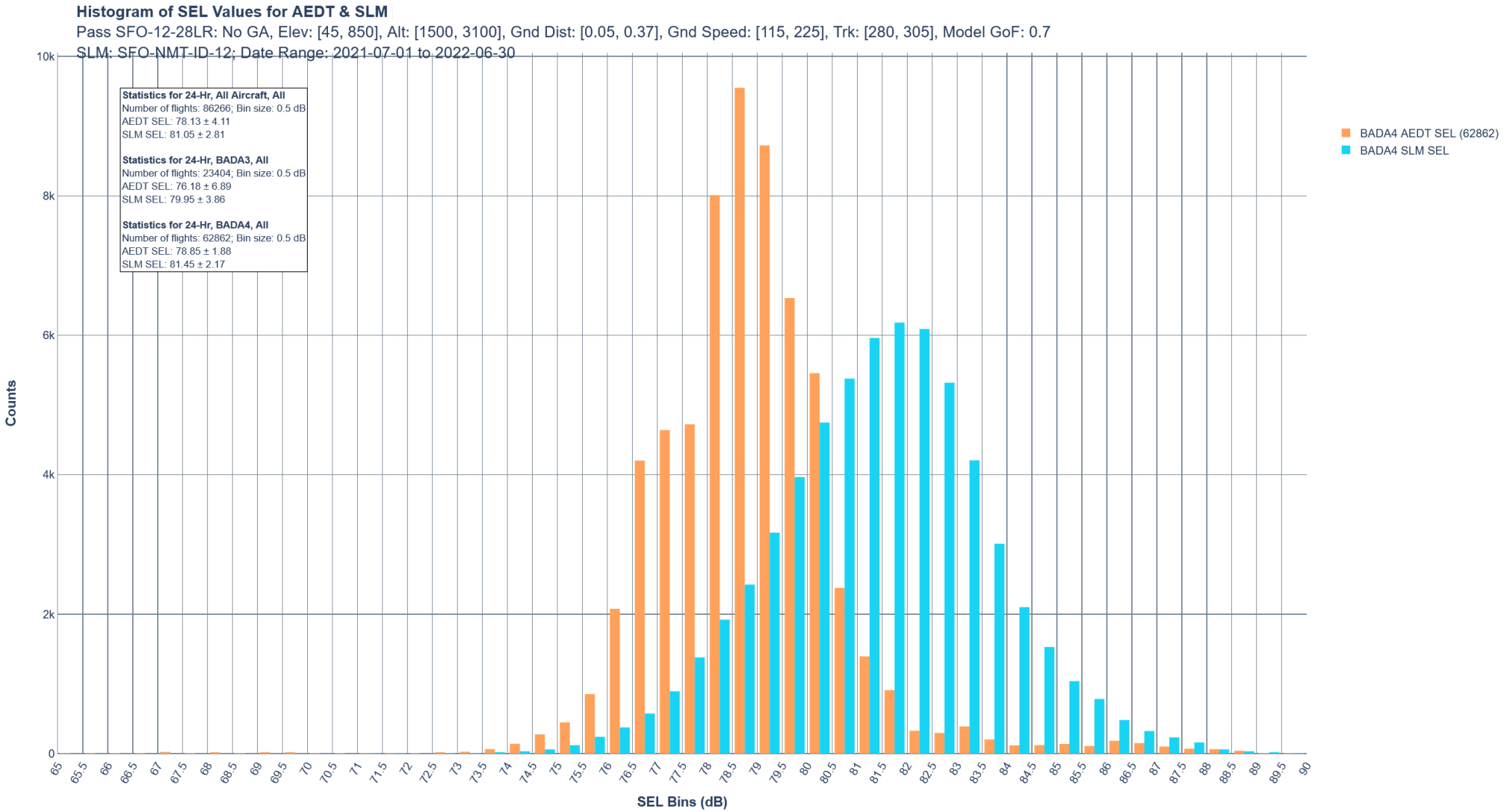


28L/R Approach LAmax: AEDT-AE vs SLM



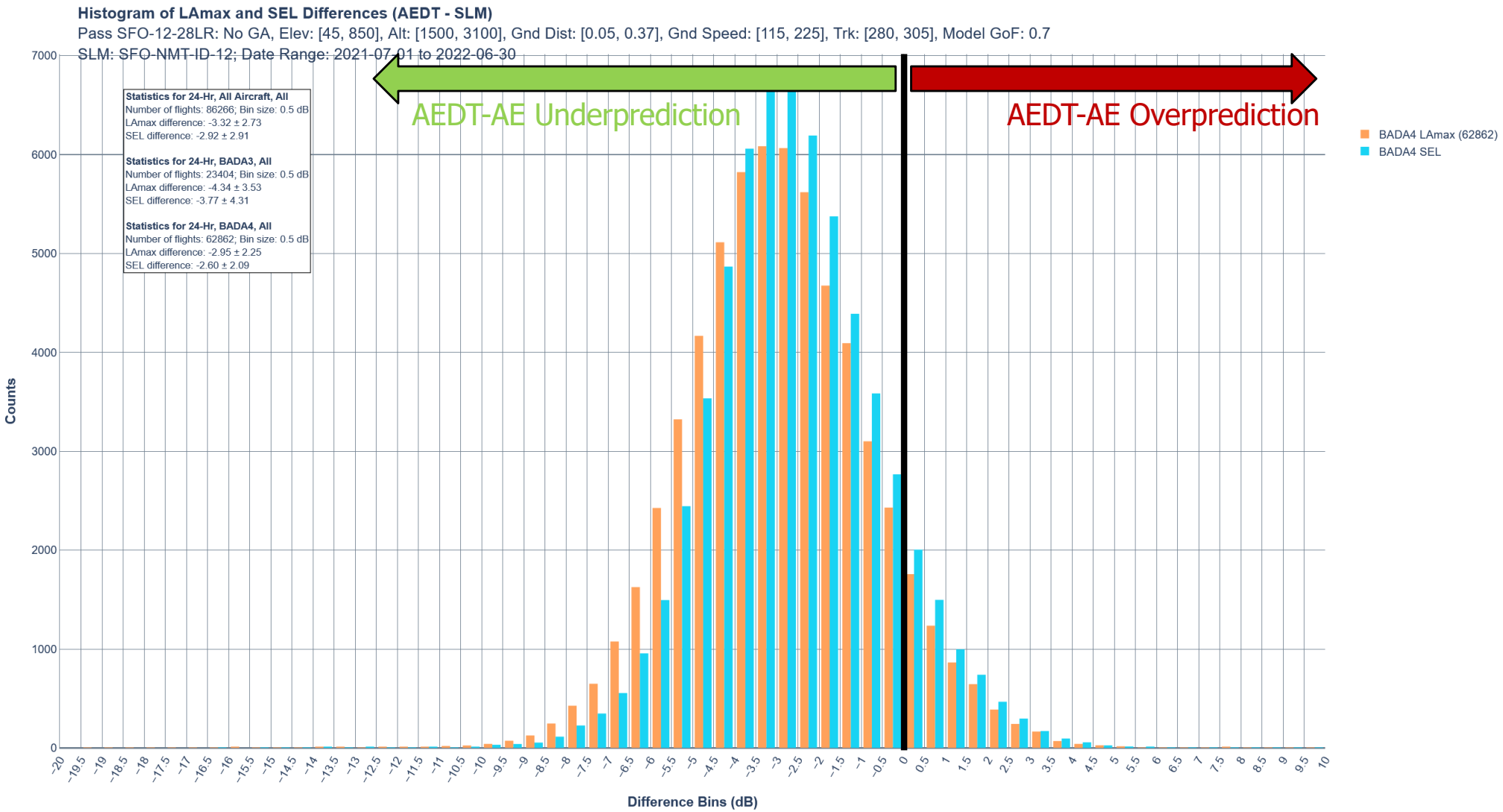
- Distribution structure due to AEDT aircraft mix not present in measurements
- BADA4 aircraft only (filtered)
- Additional analysis to understand structure (aircraft type, runway / distance, etc.)

28L/R Approach SEL: AEDT-AE vs SLM



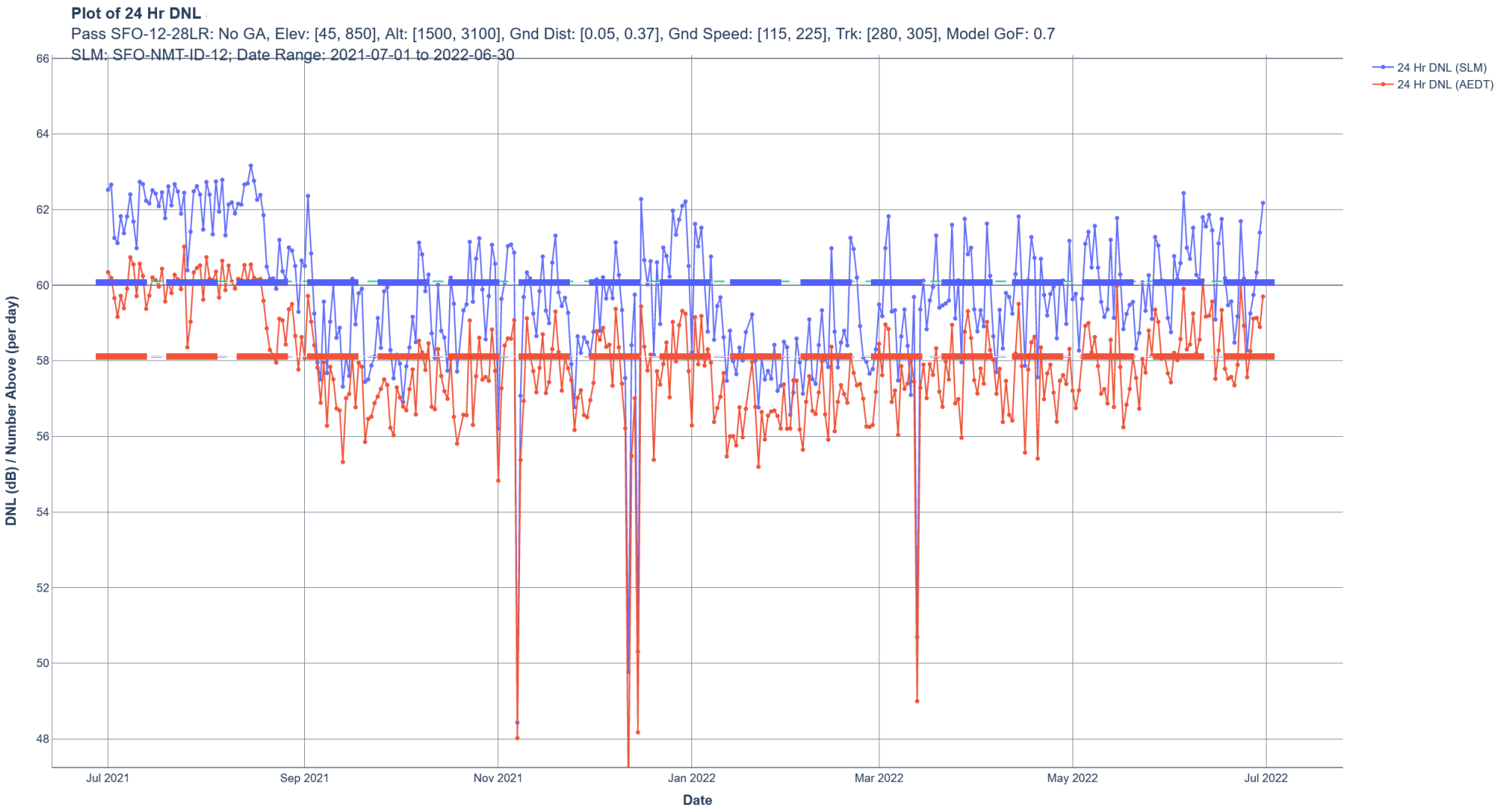
- Distribution structure due to AEDT aircraft mix not present in measurements
- BADA4 aircraft only (filtered)
- Additional analysis to understand structure (aircraft type, runway / distance, etc.)

28L/R Appr.: LAmax & SEL Differences (AEDT-AE - SLM)



- **BADA4** aircraft only (filtered)
- LAmax difference (AEDT-AE - SLM) = -2.95 dB ± 2.25 dB
- SEL difference (AEDT-AE - SLM) = -2.60 dB ± 2.09 dB

28L/R Approach: AEDT-AE vs SLM, DNL*



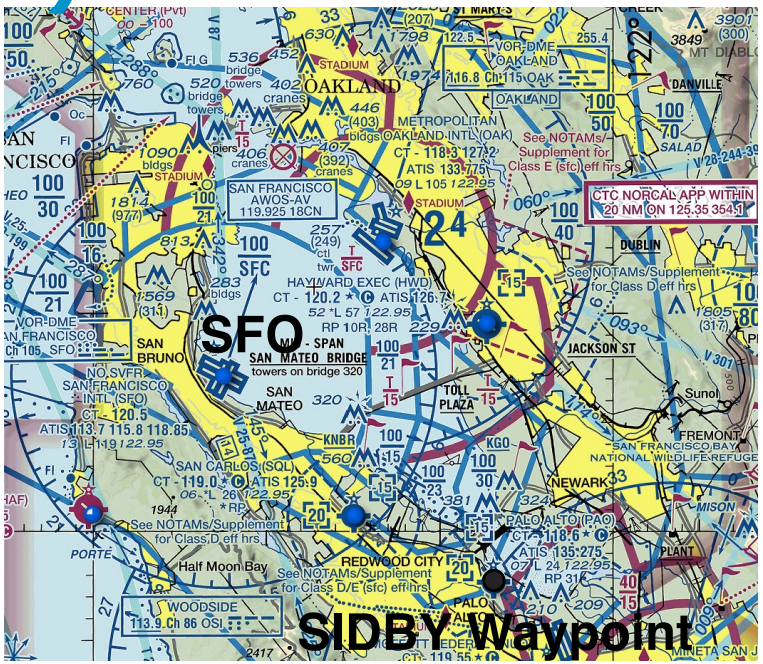
- 1-yr SLM DNL = 60.10 dB
- 1-yr AEDT DNL = 58.11 dB

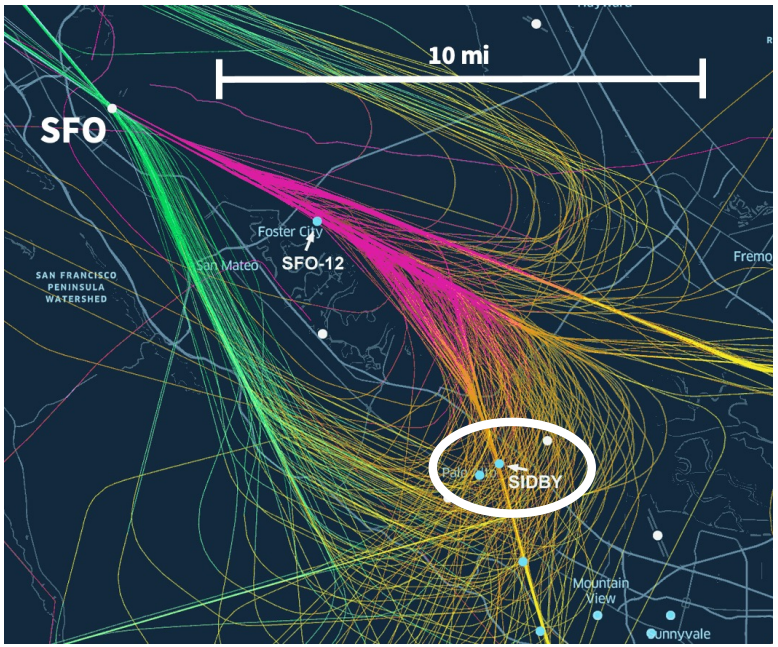
Observed difference (AEDT - SLM) = -1.99 dB

*AEDT-AE not approved for regulatory use

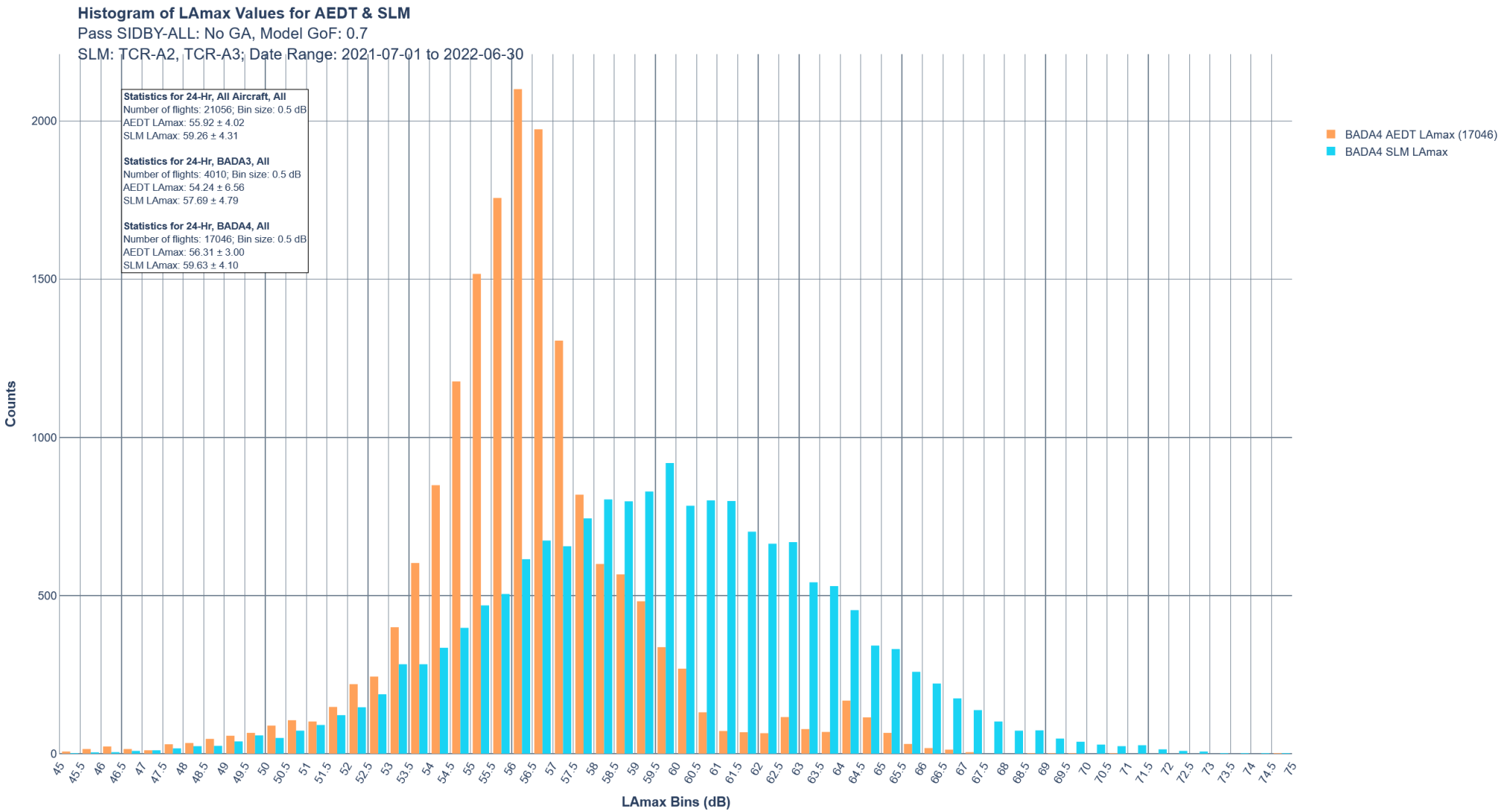
SIDBY Waypoint (Palo Alto, CA)

- Traffic into SFO 28L/R: July 1, 2021 – June 30, 2022
- Collected data for all SIDBY (SERFR, BDGA, PIRAT) and SIDBY-SERFR
- Total number of flights: 64,885
- GA aircraft flights discarded: 1,579
- Noise events removed because of low Goodness of Fit (GoF): 41,775
- Flights skipped because of multiple aircraft at PCA/TCA: 280
- Flights discarded because of trajectory criteria (altitude, distance, heading, etc.): 7,960
- MONA SLM
- **Remaining flights for 12-month period: 21,056**



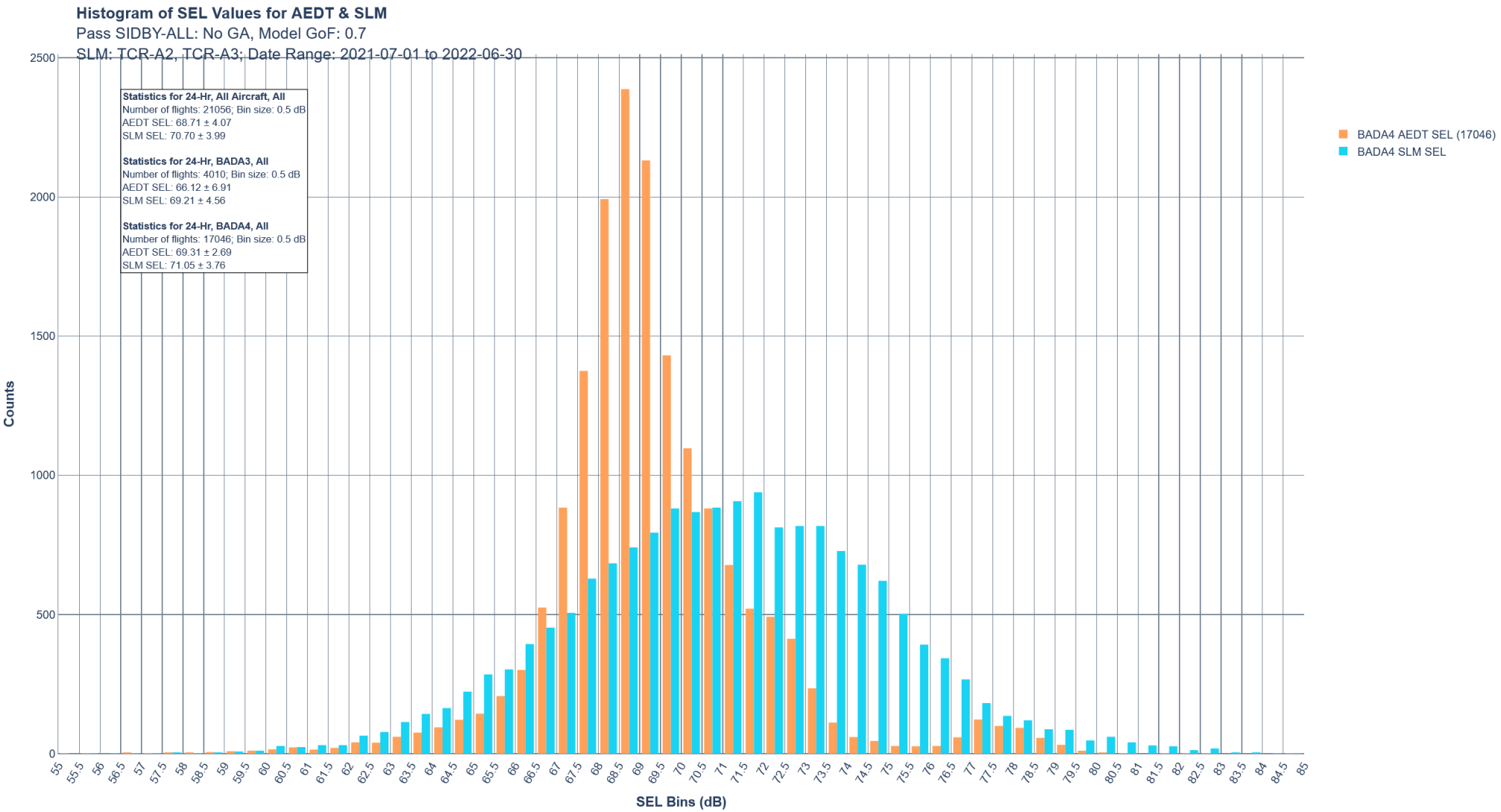


SIDBY Waypt. LAmax: AEDT-AE vs SLM



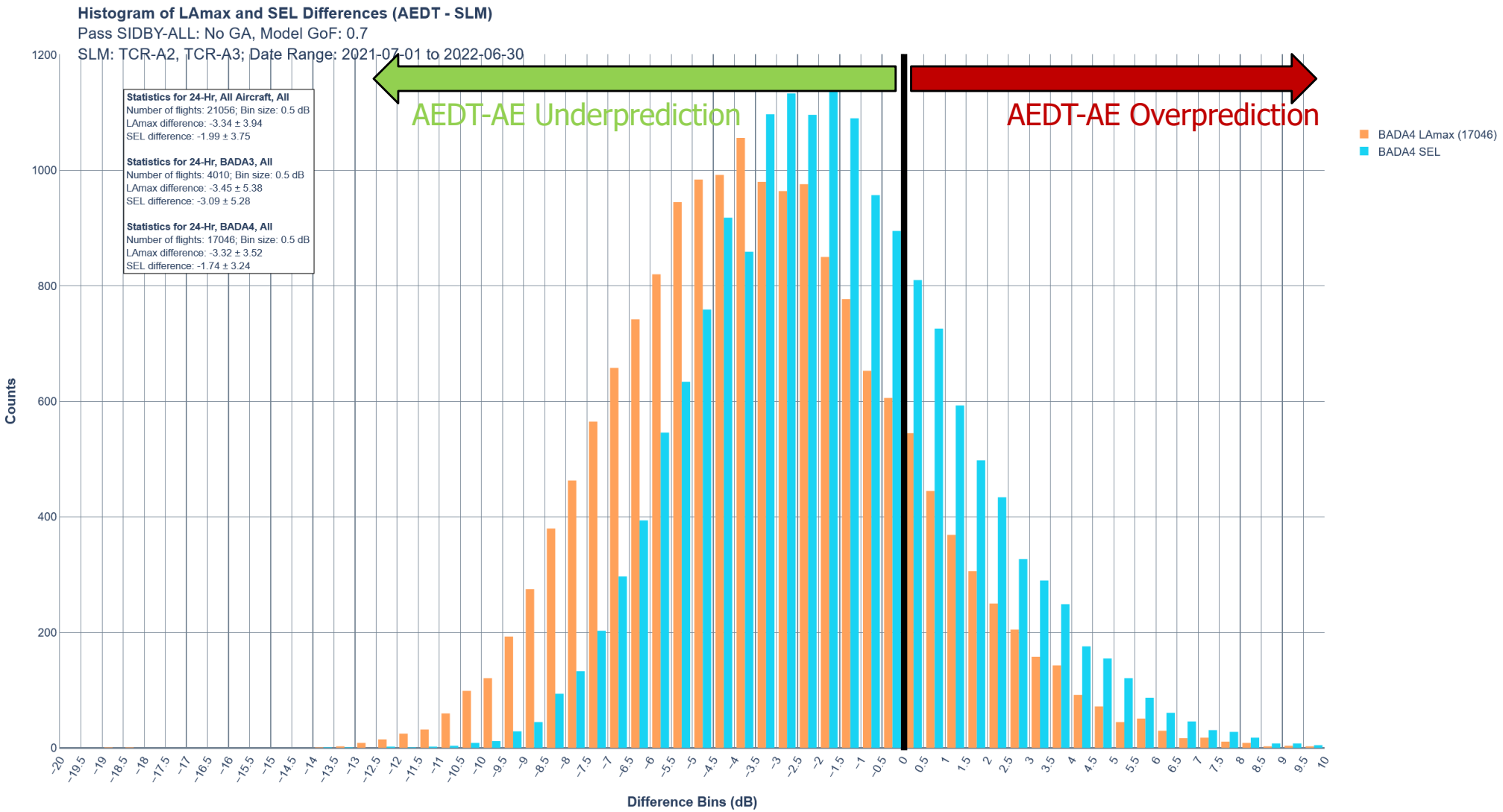
- Distribution structure due to AEDT aircraft mix not present in measurements
- BADA4 aircraft only (filtered)
- Additional analysis to understand structure (aircraft type, runway / distance, etc.)

SIDBY Waypoint SEL: AEDT-AE vs SLM



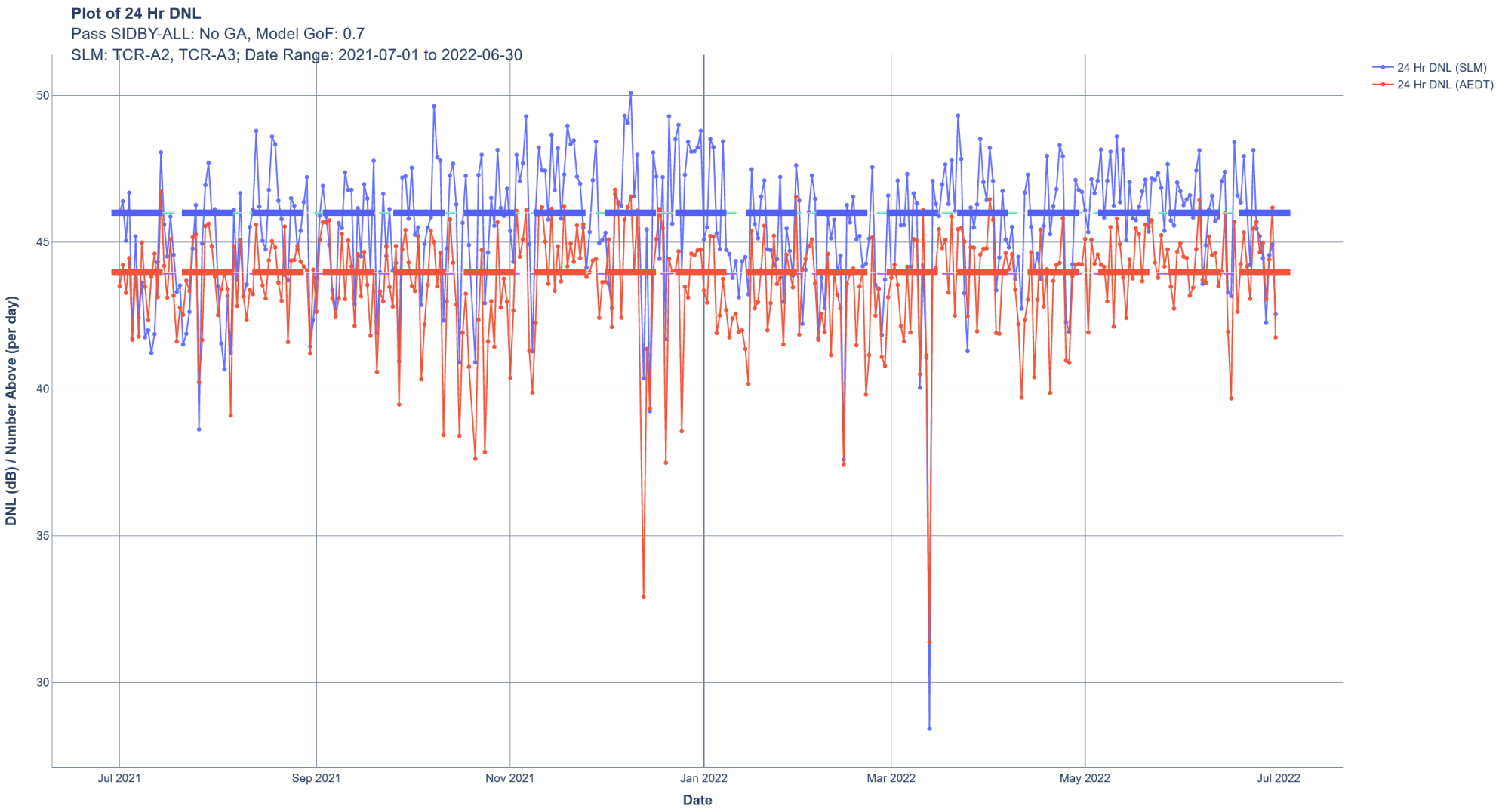
- Distribution structure due to AEDT aircraft mix not present in measurements
- BADA4 aircraft only (filtered)
- Additional analysis to understand structure (aircraft type, runway / distance, etc.)

SIDBY Waypt: LAmax & SEL Differences (AEDT-AE – SLM)



- **BADA4** aircraft only (filtered)
- LAmax difference (AEDT-AE - SLM) = -3.32 dB ± 3.52 dB
- SEL difference (AEDT-AE - SLM) = -1.74 dB ± 3.24 dB

SIDBY Waypt: AEDT-AE vs SLM, DNL*

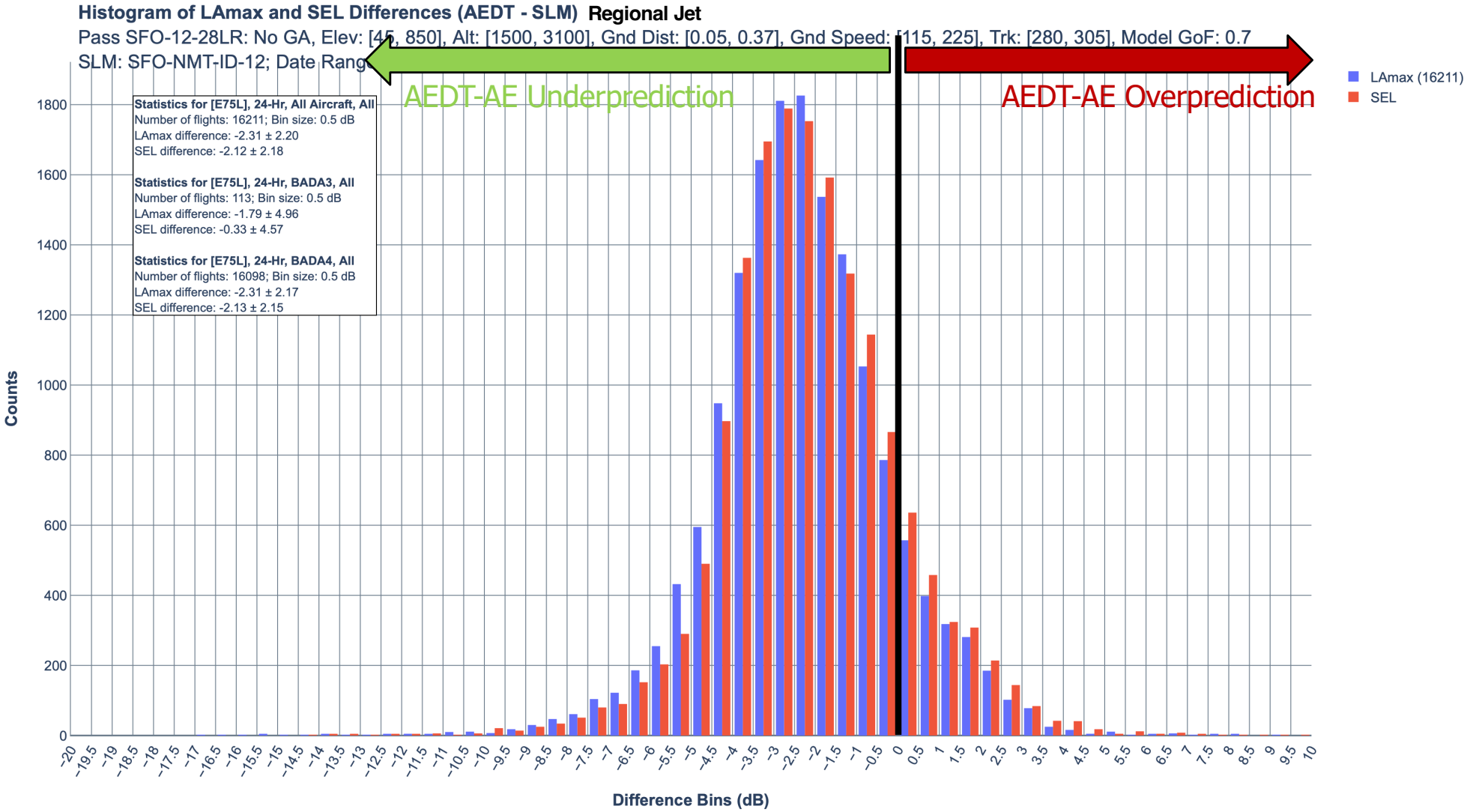


- 1-yr SLM DNL = 46.00 dB
- 1-yr AEDT DNL = 43.92 dB

Observed difference (AEDT - SLM) = -2.08 dB

*AEDT-AE not approved for regulatory use

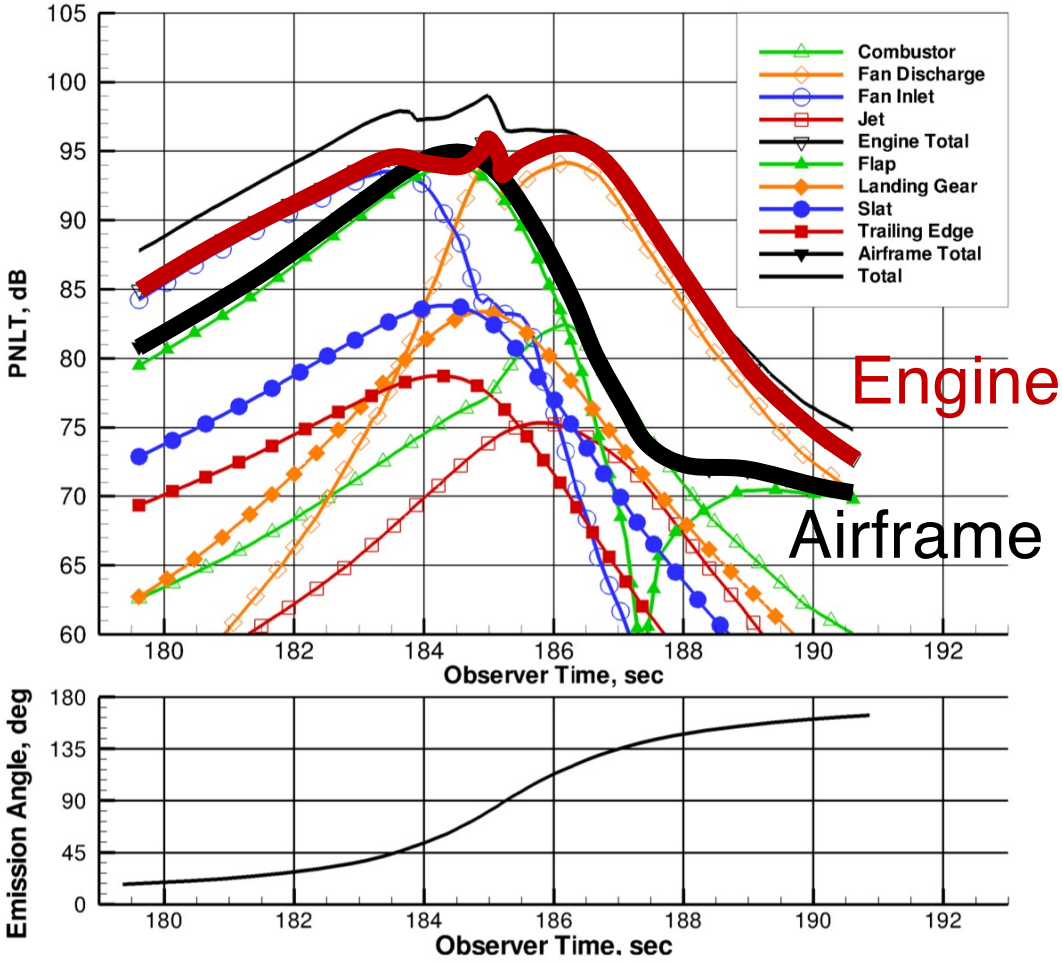
28L/R Approach: LAmax and SEL differences



- Significant differences in prediction accuracy between aircraft types
- Most likely explains multi-modal (of AEDT) vs Gaussian (of SLM) distributions
- Potential opportunity for improvement, after additional validation

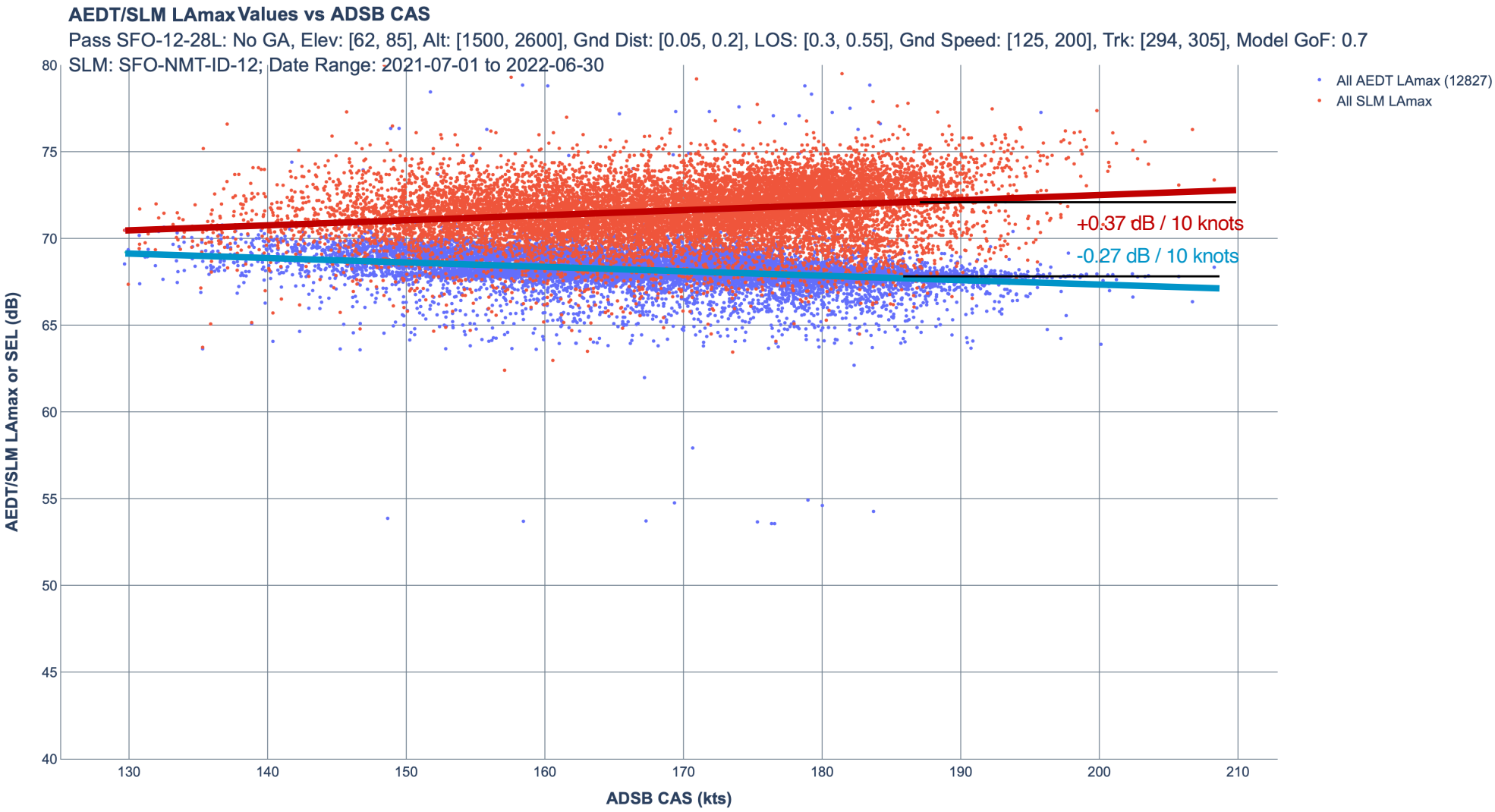
Noise Level vs CAS – 28L/R Approach

- Observations on airspeed independence of noise predictions from AEDT
- NPD curves are based on thrust levels and distance
- Particularly on approach, airframe noise can be as large as engine noise (3 dB difference)
- Higher CAS should result in higher noise levels
- We find the opposite trend in AEDT-AE's predictions (noise model was developed for near-airport areas where most of the noise is engine noise)
- Very significant opportunity for prediction improvement



ANOPP2 component noise predictions for conventional aircraft in approach
from Lopes & Burley, AIAA 2011-2854, 17th AIAA/CEAS Aeroacoustics Conference

28L/R Approach: AEDT-AE LAmax vs CAS

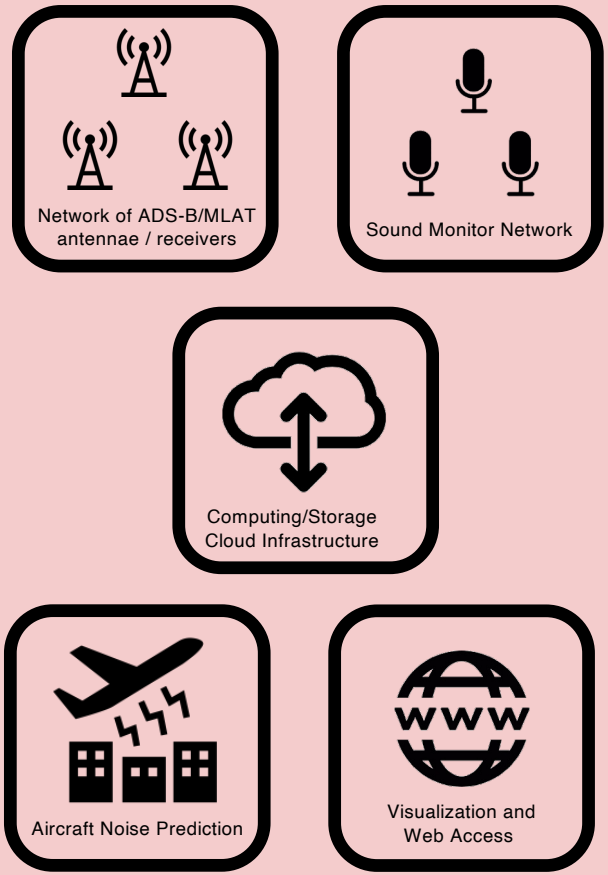


- Data at SFO-NMT-12 PCA for SFO 28L approaches
- Single aisle aircraft shown (12,827 flights)
- Measured = +0.37 dB / 10 knots; Predicted = -0.27 dB / 10 knots

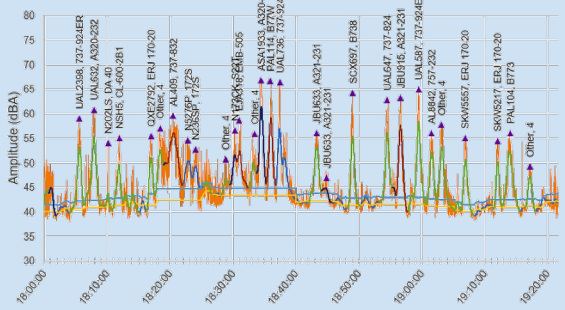
MONA Infrastructure Details

MONA System Overview

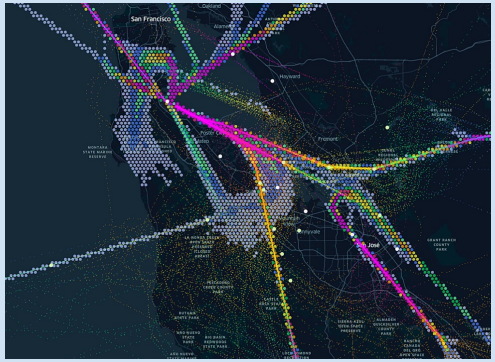
System Architecture



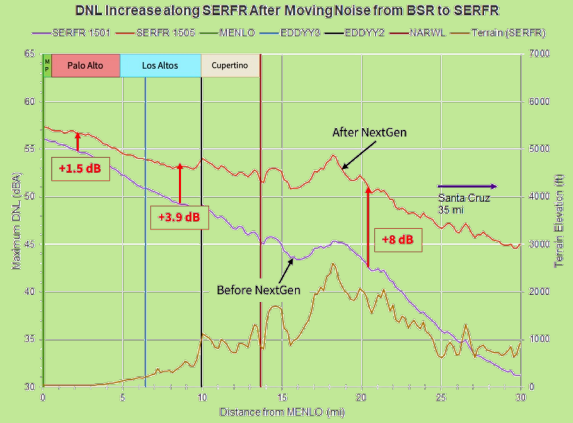
MONA ADS-B / Sound Monitor station



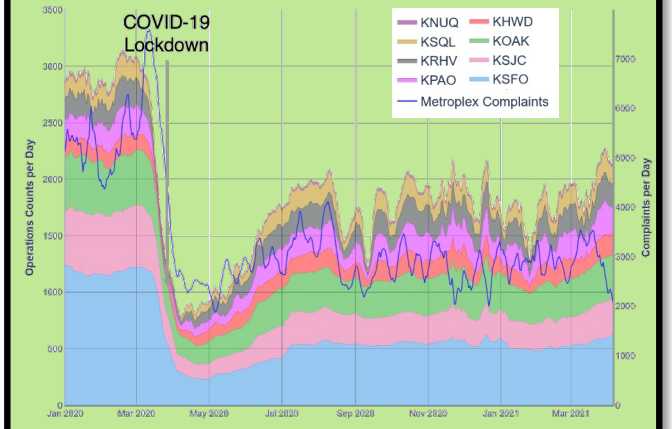
Non-aircraft noise removal algorithm



Noise metric interactive visualization



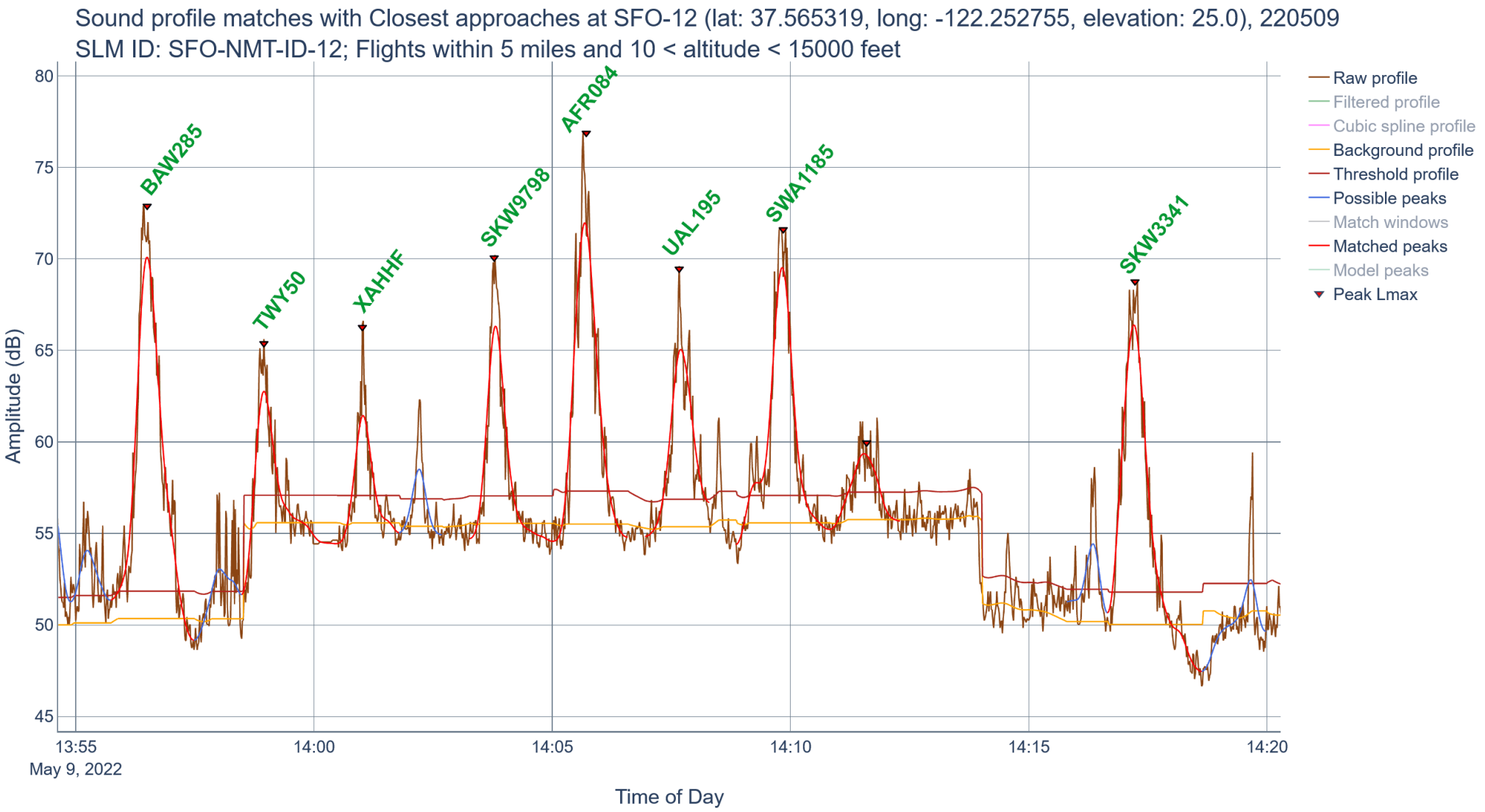
Sample study of NextGen route changes



MONA historical traffic / complaints data during 2020-21 pandemic

- Data (ADS-B and sound) collection, storage/compute infrastructure
- Open-source, scalable, platform to automatically perform analyses (AEDT), studies, visualizations
- Best-in-class algorithms / tools for data processing and predictions

SLM Data Processing / Curation



AEDT-AE Modeling Observations

- Analysis of nearly 100,000 flights points to underestimation of AEDT-AE predictions for individual-event sound levels by ~2.95/3.32 dB (at 28L/R Approach and SIDBY Waypoint, respectively) regardless of DNL level
- Preliminary analyses suggest BADA4 results in significantly more accurate noise predictions than ANP standard profile modeling. BADA4 lacks models for some aircraft types. **Presented analysis discards flights for which BADA4 models are not available**
- Measured variability for same aircraft types is *very significant* with std dev ~ 3-5 dB: important area to understand better. Would like to obtain FOQA data or to estimate / infer aircraft weight and state
- Incorrect noise-level trend with airspeed observed: potential shortcoming of NPD-based predictions in low-noise areas
- Various improvements suggested by data analysis:
  - Include airframe noise elements
  - Improve NPD curves (or equivalent), especially for larger distances from airport
  - Better weather models
  - Measure or estimate aircraft weight and state

Caveats

- Currently focused exclusively on SFO arrivals (departures next)
- Close examination of only 2 SLM locations

But

- Over 100,000 data points
- Across an entire year with seasonal weather variations
- Analyzed the data with different aircraft types
- Analyzed both individual-flight and aggregate metrics
- Careful curation of the data (esp. noise events) that were used for these comparisons

Ongoing Efforts & Future Plans

- Examination of predictive capabilities with alternative modeling
  - AEDT-AE: BADA4 + Altitude + Speed controls – 1 year of data
  - AEDT ANP + Altitude controls – 1 year of data
  - AEDT ANP + Standard profiles – 1 year of data
  - AEDT BADA4 + Standard profiles – 1 year of data
- Continued in-depth analysis of AEDT results including:
  - Additional SLM locations (from SFO and MONA installations)
  - Analysis of departures in addition to arrivals
  - Continuing work for discrepancy attribution and sensitivity analysis
  - Potentially expand to other airports in Bay Area metroplex to collect larger amounts of data under different conditions
- Dig into reasons for variation of AEDT metric estimates
  - Flight operations data (throttle settings, high-lift system deployment, vectoring and ATC instructions, aircraft weight, airspeed, etc.)
  - AEDT model limitations (Noise Power Distance tables, calculation model selection)
- Ongoing MONA system development, refinement, and deployment
  - Improvements to automation, study creation / execution, performance, visualization, data science, AI/ML based noise models

Acknowledgements

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  - Current: Brian Munguia, Sanjaye Narayan, Aditeya Shukla
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- San Francisco International Airport & Envirosuite
  - Bert Ganoung and Simon Heath