Single-Stream Empirical Jet Noise Models Based on Scale-Model Data

Commercial Supersonic Technology Project
Advanced Air Vehicles Program

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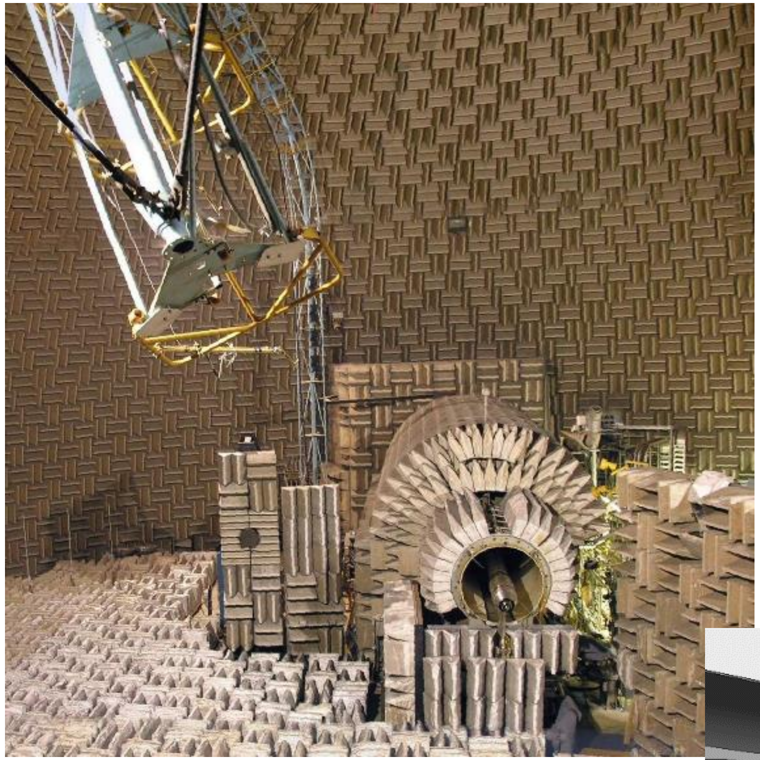
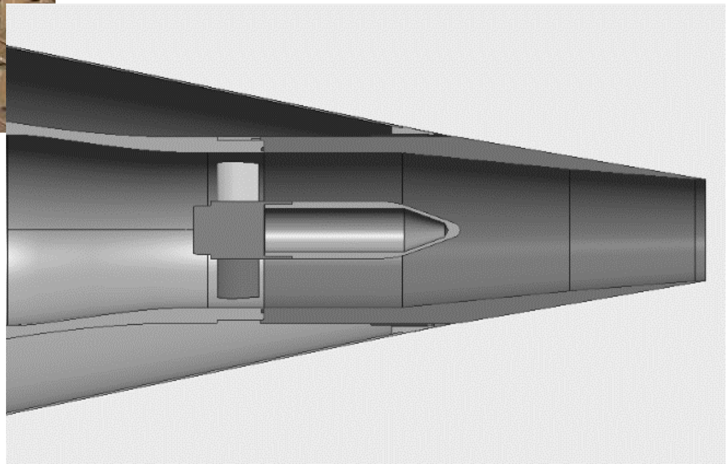
Why A New Single-Stream Model?

- Renewed interest in commercial supersonic flight led NASA to conduct system studies in support of ICAO efforts
- Jet-noise was identified as the dominant noise source at lateral and flyover locations
- Near-term entry into service aircraft will likely be business jets with internally mixed core and fan streams resulting in single-stream type exhausts
- Exhausts are expected to be at high subsonic or low supersonic speeds and dominated by mixing noise
- Comparisons between existing prediction tools and scale-model data indicated the prediction tools needed to be improved to reduce the uncertainty of jet-noise predictions
- Current study is focused on empirical predictions for subsonic scale-model jets with simulated **flight**

Scale-Model Experiments



AAPL Facility



Single-Stream Nozzle

- Experiments were conducted in NASA's Aero-Acoustic Propulsion Laboratory (AAPL)
- A single-stream 3.51" diameter nozzle was used for the data presented here
- Data for a larger diameter nozzle has been acquired and will be compared to the model in future efforts

Empirical Modeling Approach

- For static case
  - Use approach from Viswanathan, K. and Czech, M. J., AIAA J. Vol. 45, No. 1, 2007, pp. 151-161.
  - For a given NTR (nozzle temperature ratio), data collapses when scaled by a power of the velocity or acoustic Mach number and plotted against Strouhal number
  - From the data collapse, master spectra are obtained
- For flight conditions, models are slightly modified from static models

Current Model

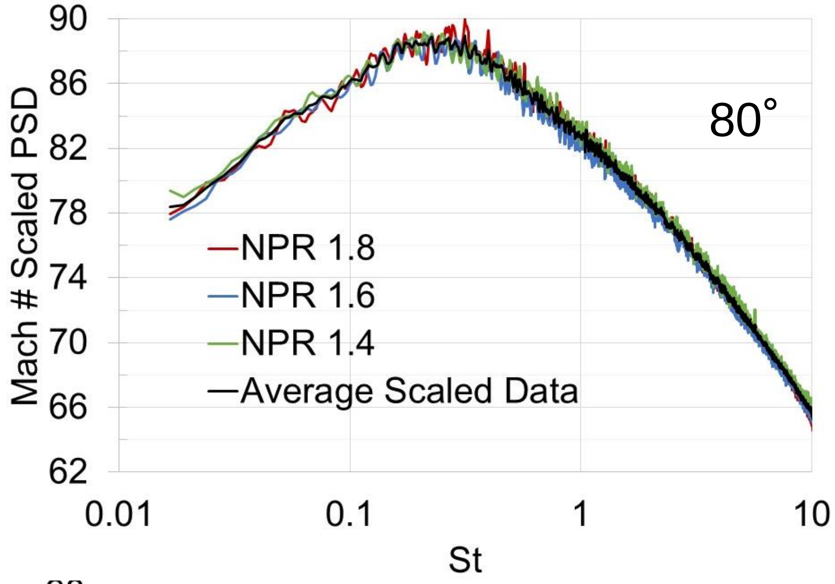
- Use narrowband acoustic data in power spectral density (PSD) with 12.2 Hz binwidth for the same NTR
- Determine the power (*n*) of the acoustic Mach number (*M*) that collapses the data when plotted against Strouhal number
  - The velocity used for the Mach number is given by the difference in the jet velocity and the flight velocity
  - The power is determined by minimizing the square error between the different data sets
- Obtain an average normalized spectrum from the data scaled
- Fit a peak function, $PSD_M(St)$, to the resulting Mach # scaled average spectra

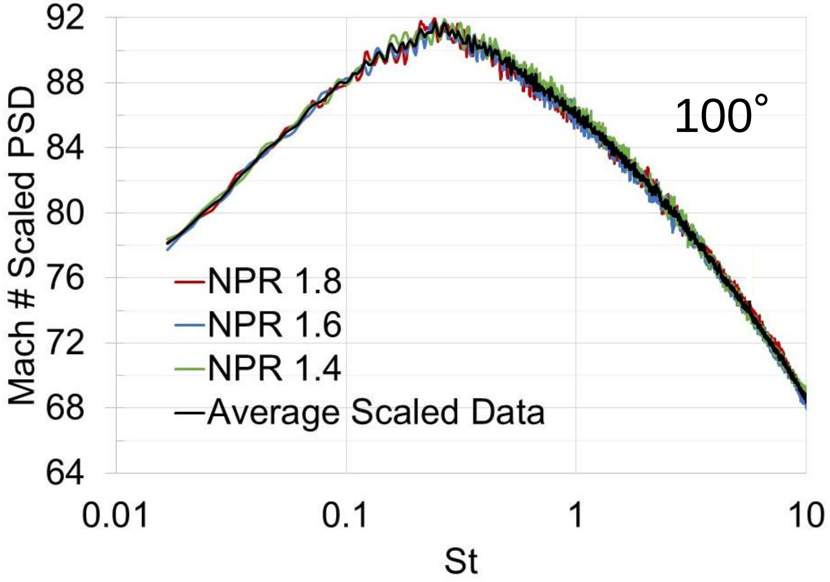
$$PSD_M(St) = \frac{H}{\left\{1 + \lambda_l exp\left[{(t_l - \log_{10} St)}/{k_l}\right]\right\}^{m_l} + \left\{1 + \lambda_t exp\left[{(\log_{10} St - t_t)}/{k_t}\right]\right\}^{m_l}}$$

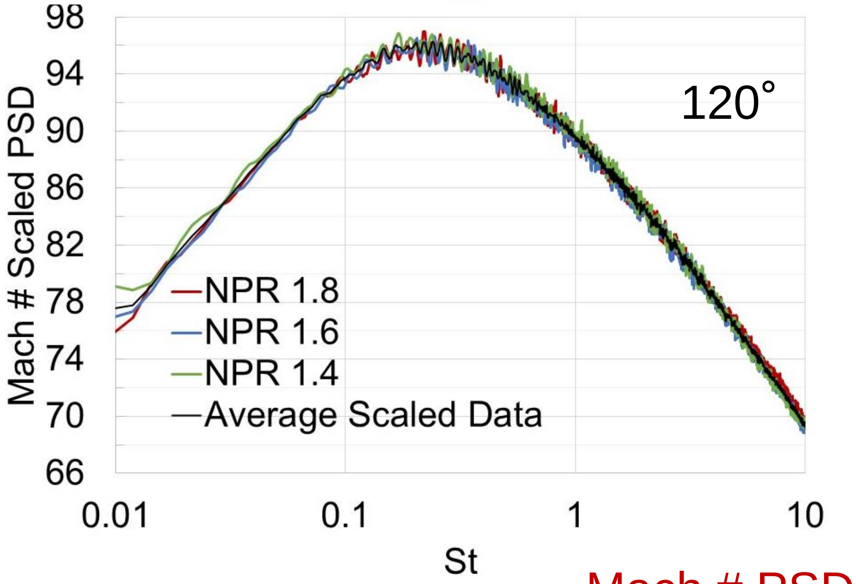
  - l indicates leading edge, *t* indicates trailing edge, *H* impacts the peak level
- Modify the peak function to estimate the normalized spectra acquired with simulated flight

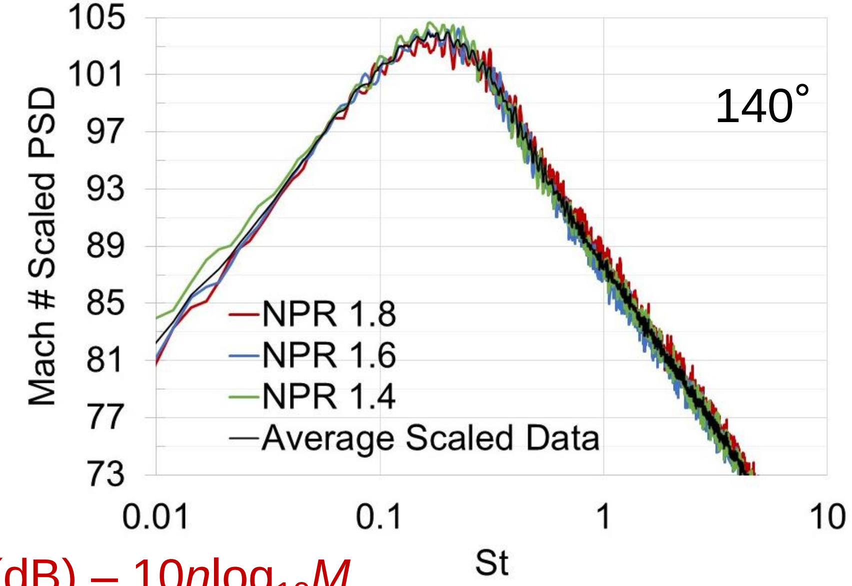
Static Jets

Typical Data Collapse





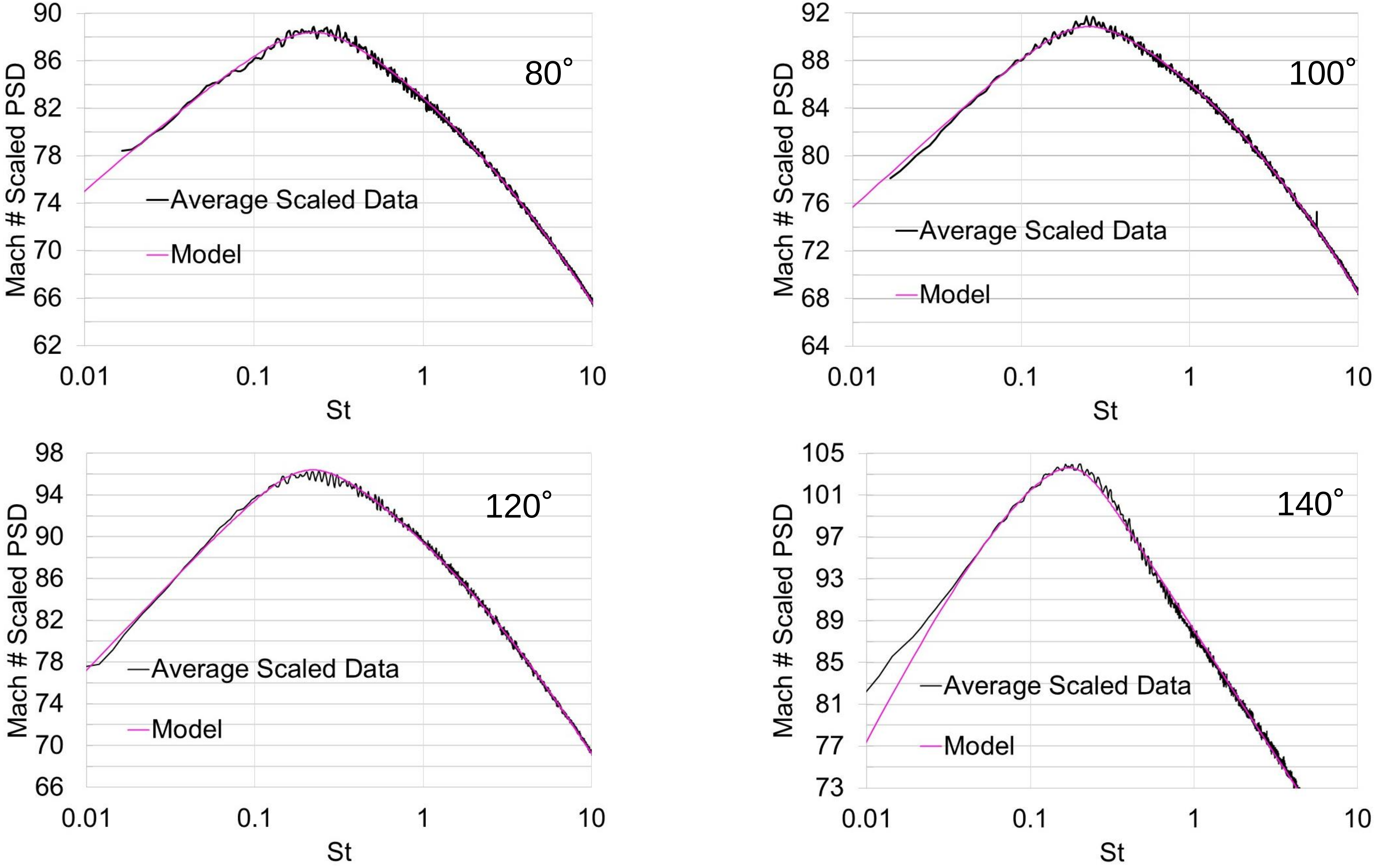




NTR = 2.5

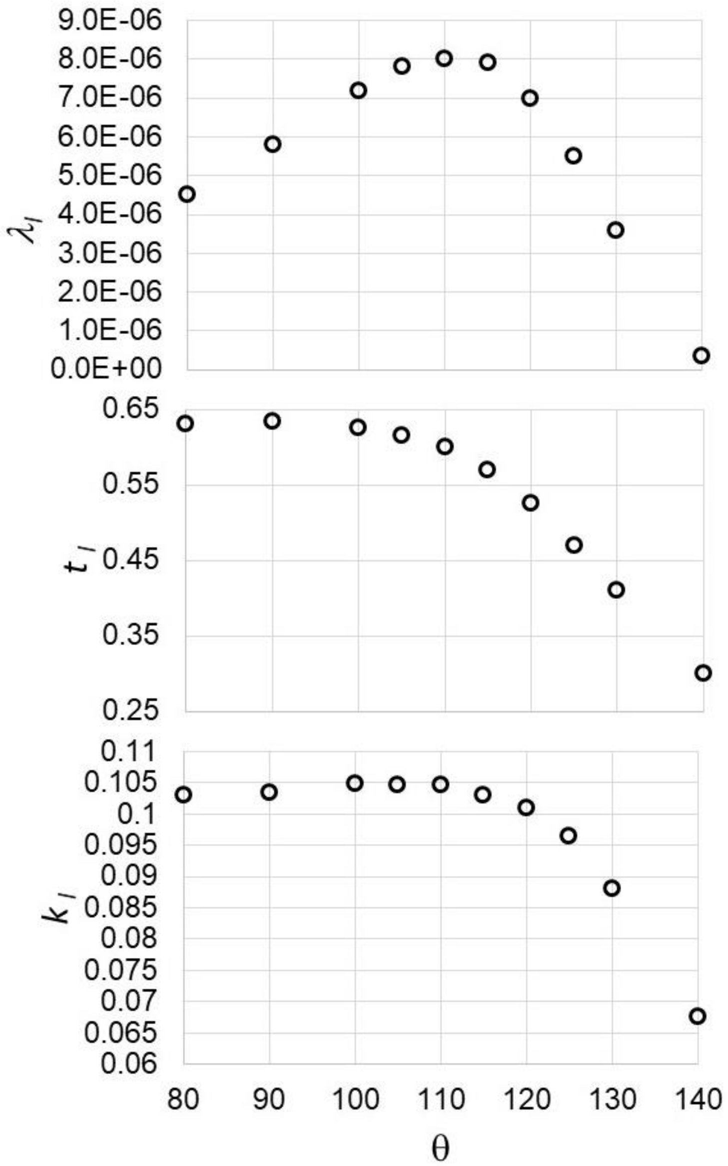
Mach # PSD = PSD(dB) – $10n\log_{10}M$

Typical Model Results

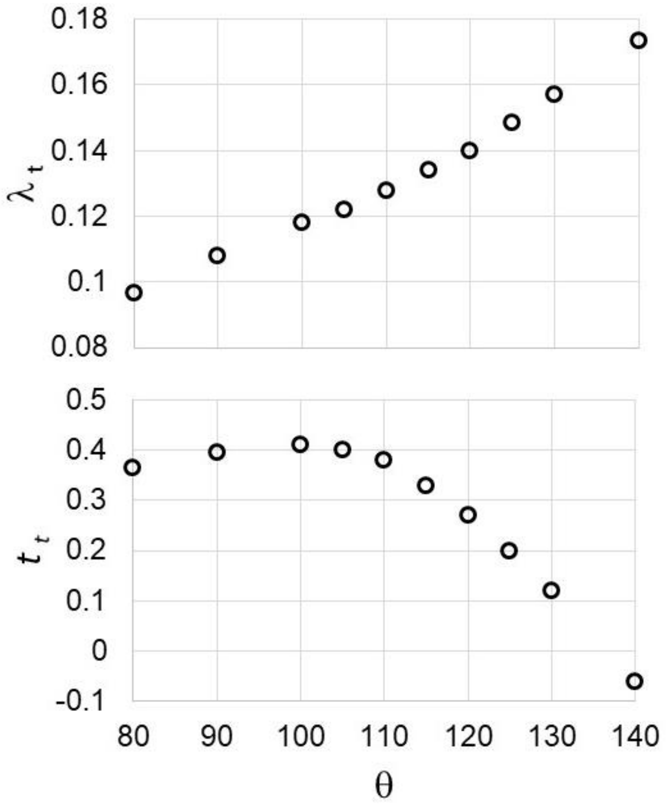


NTR = 2.5

Model Coefficients Depending on θ

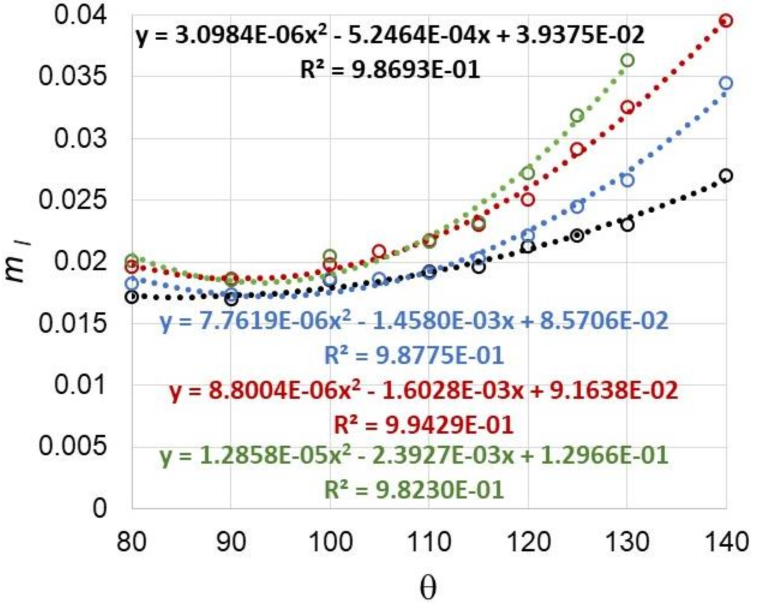


Leading-Edge Coefficients

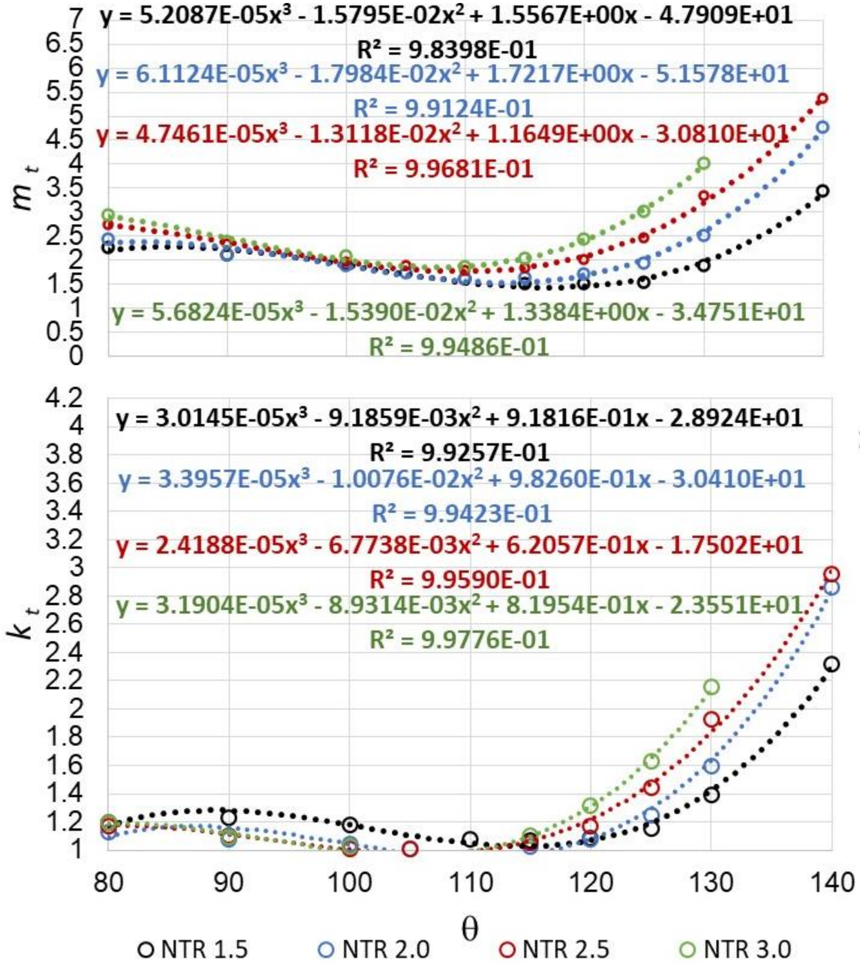


Trailing-Edge Coefficients

Model Coefficients Depending on θ and NTR

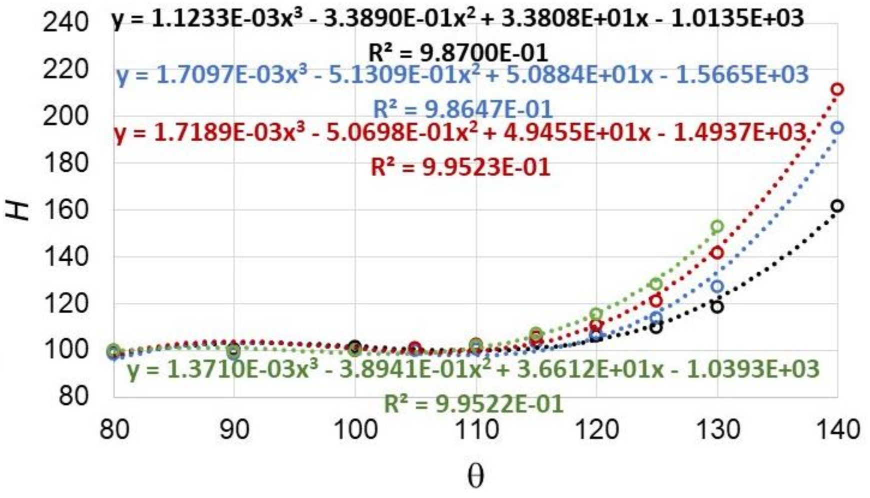


Leading-Edge Coefficients



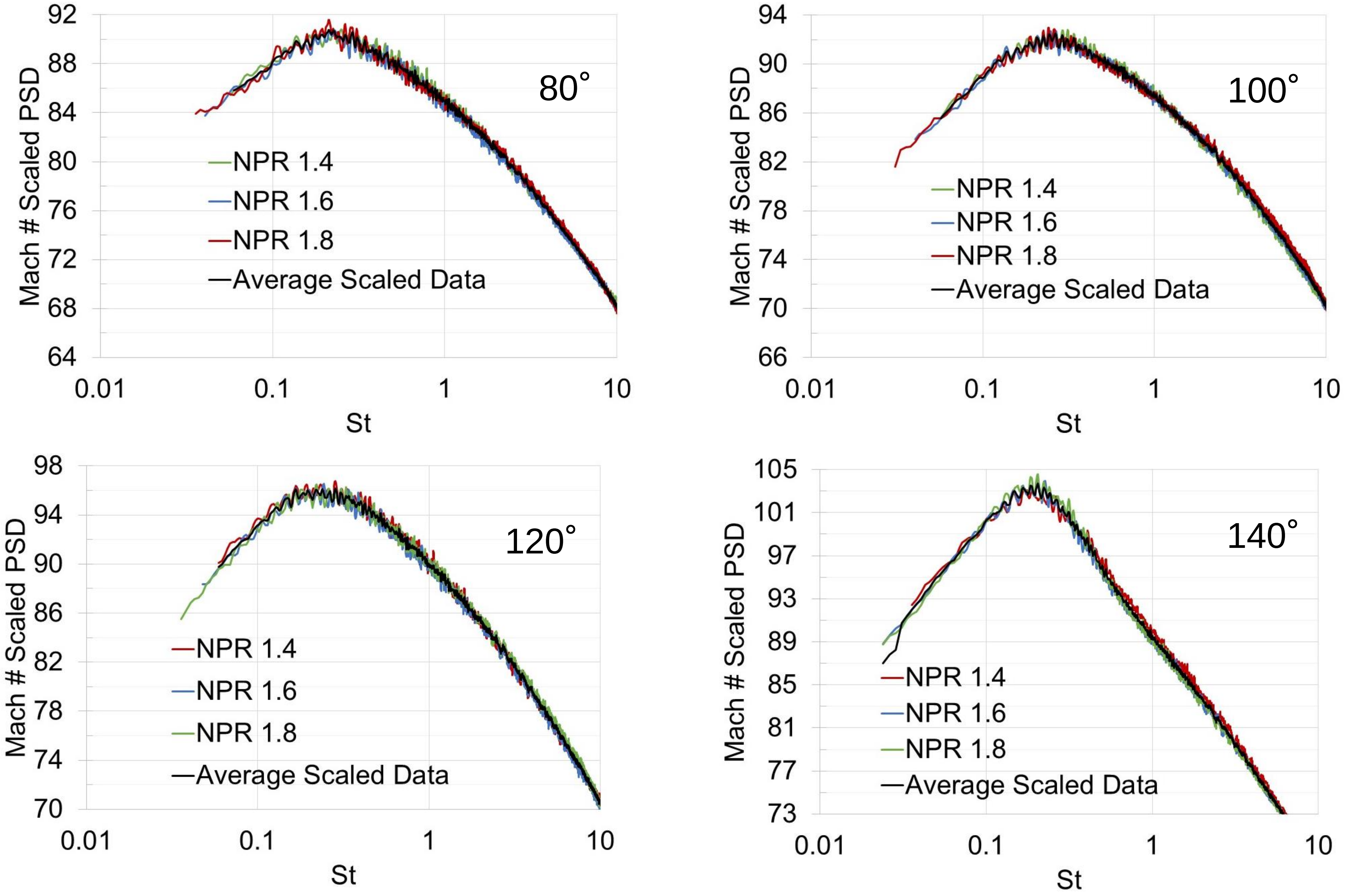
Trailing-Edge Coefficients

Values for *n* are found in the full paper



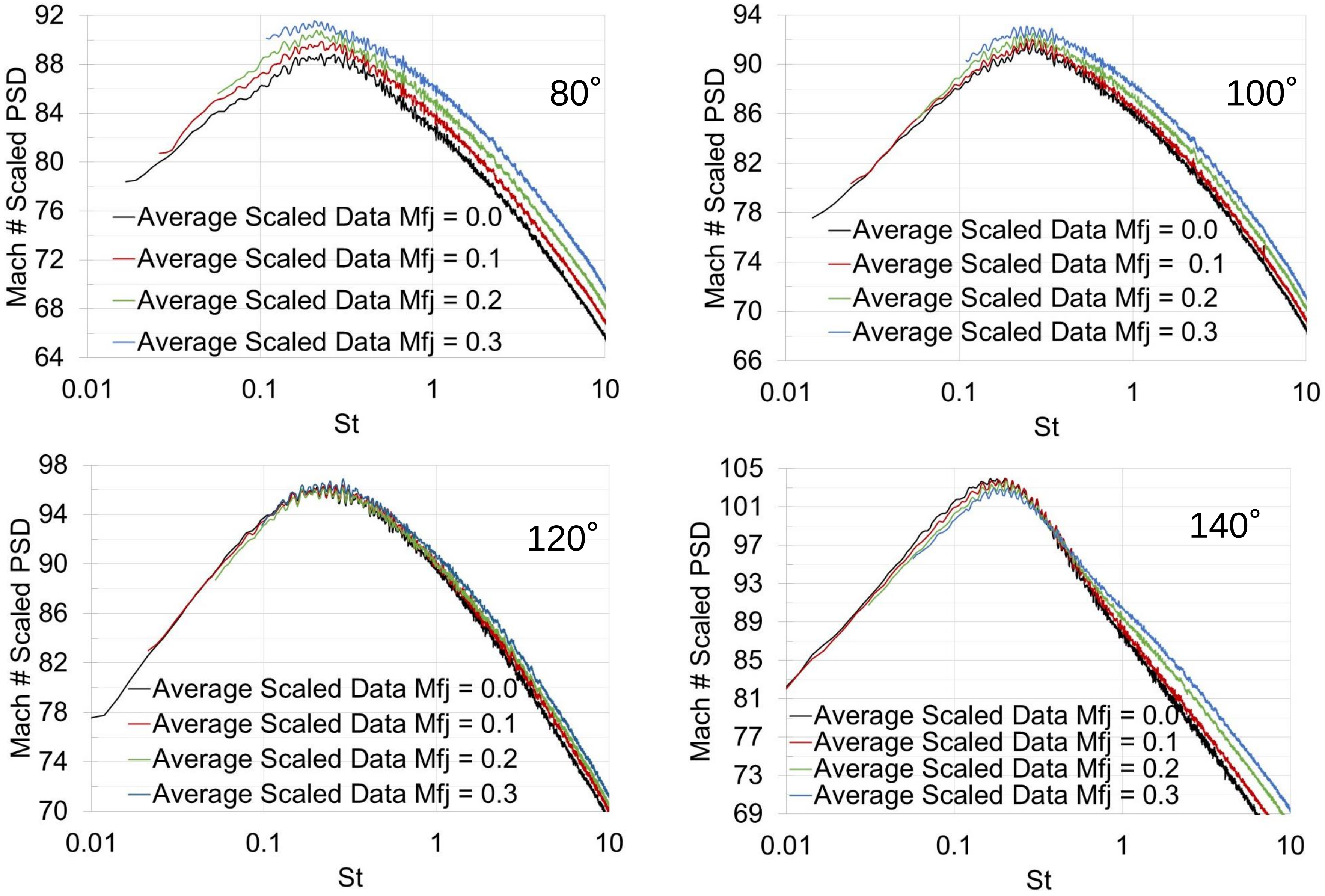
Jets With Simulated Flight

Typical Data Collapse



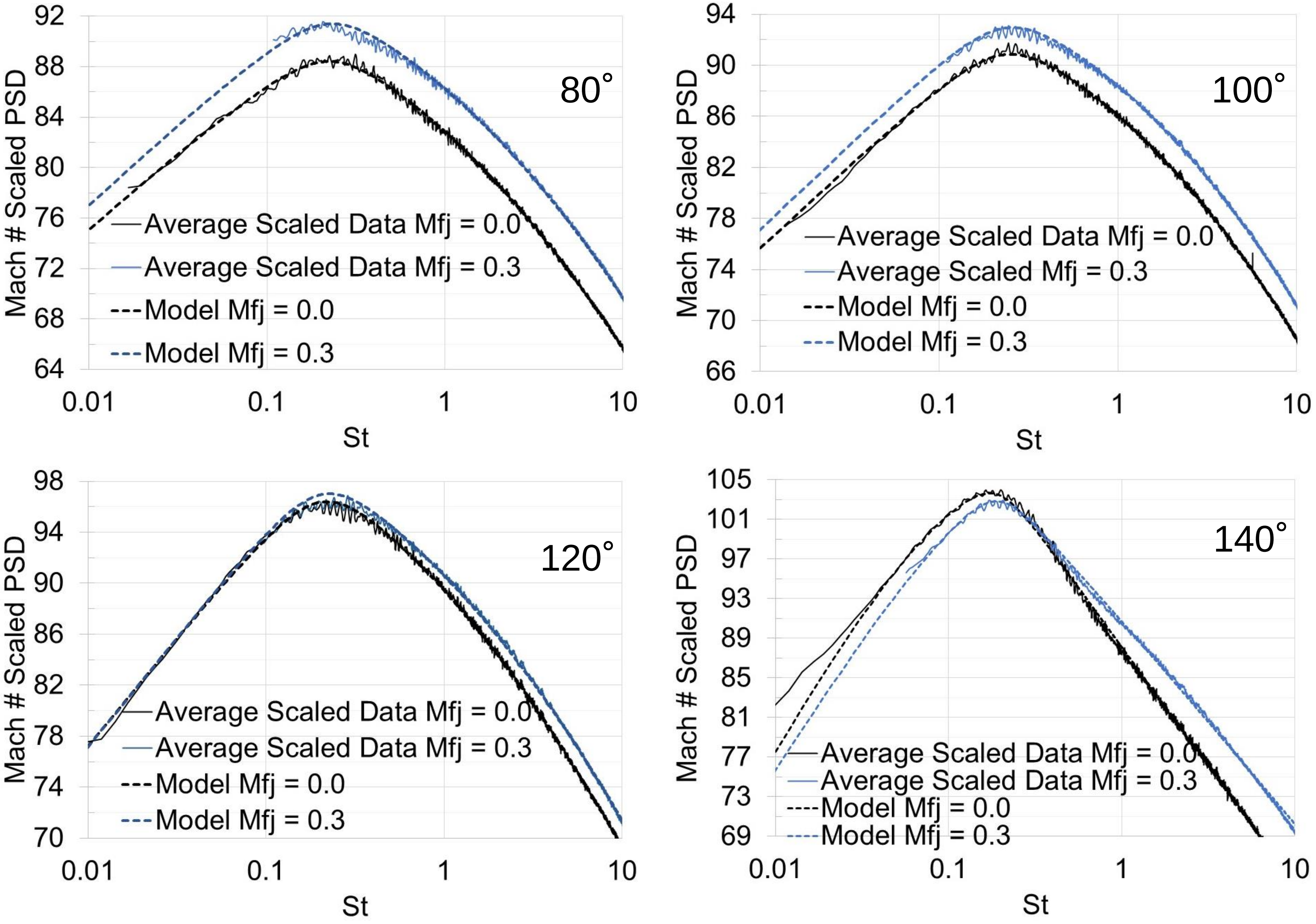
NTR = 2.5
Flight Mach # = 0.2

Variation With Flight Mach Number



NTR = 2.5

Typical Model Results

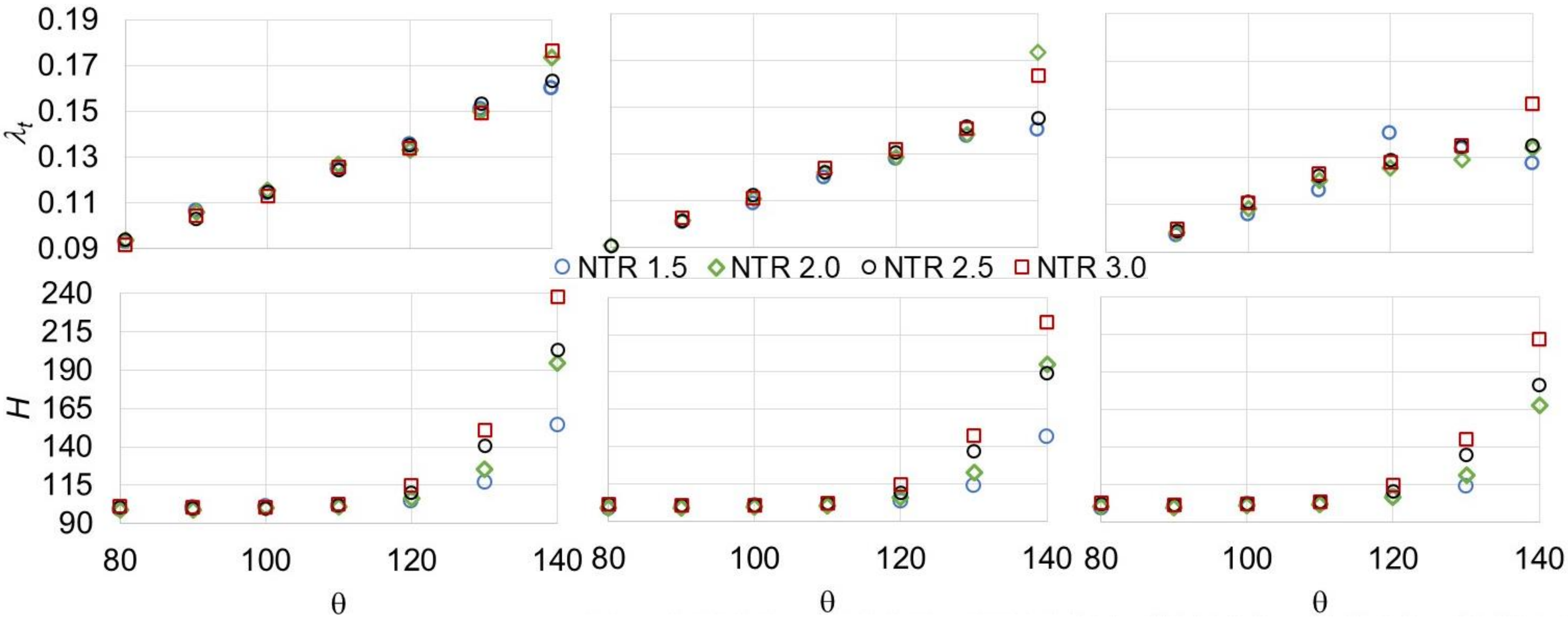


NTR = 2.5

Values for *n* are shown in the full paper

Model Coefficients

Flight Mach # = 0.1 | Flight Mach # = 0.2 | Flight Mach # = 0.3



m_l was modified for some conditions at 140° (see full paper)

Conclusions

- Empirical models for predicting mixing noise from subsonic scale-model jets have been developed
  - Static and flight conditions
- The models can be used to produce narrowband spectra