Experimental Validation of Low Temperature Viscosity Predictions for Sustainable Aviation Fuels

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Research Objective: To validate viscosity extrapolation and blending models at low temperatures, so that errors can be minimized in prescreening property prediction.

Introduction

- Sustainable Aviation Fuels (SAFs) identified as an opportunity for aviation sector to reduce CO_2 emissions
- SAF approval for commercial use is time and material expensive. Prescreening pathway developed to curb these costs.
- Prescreening includes 2 tiers: property prediction and testing for proposed SAFs[1]
- Tier Alpha focuses on physical and chemistry property prediction to determine if proposed SAF will fall within operability limits.[2]
- Viscosity, particularly at -40 and -20°C, key property for ignition probability prediction

Methodology

Viscosity Prediction Models

- ASTM D341 Extrapolation

$$\log\log(\nu + 0.7) = A - B\log T$$

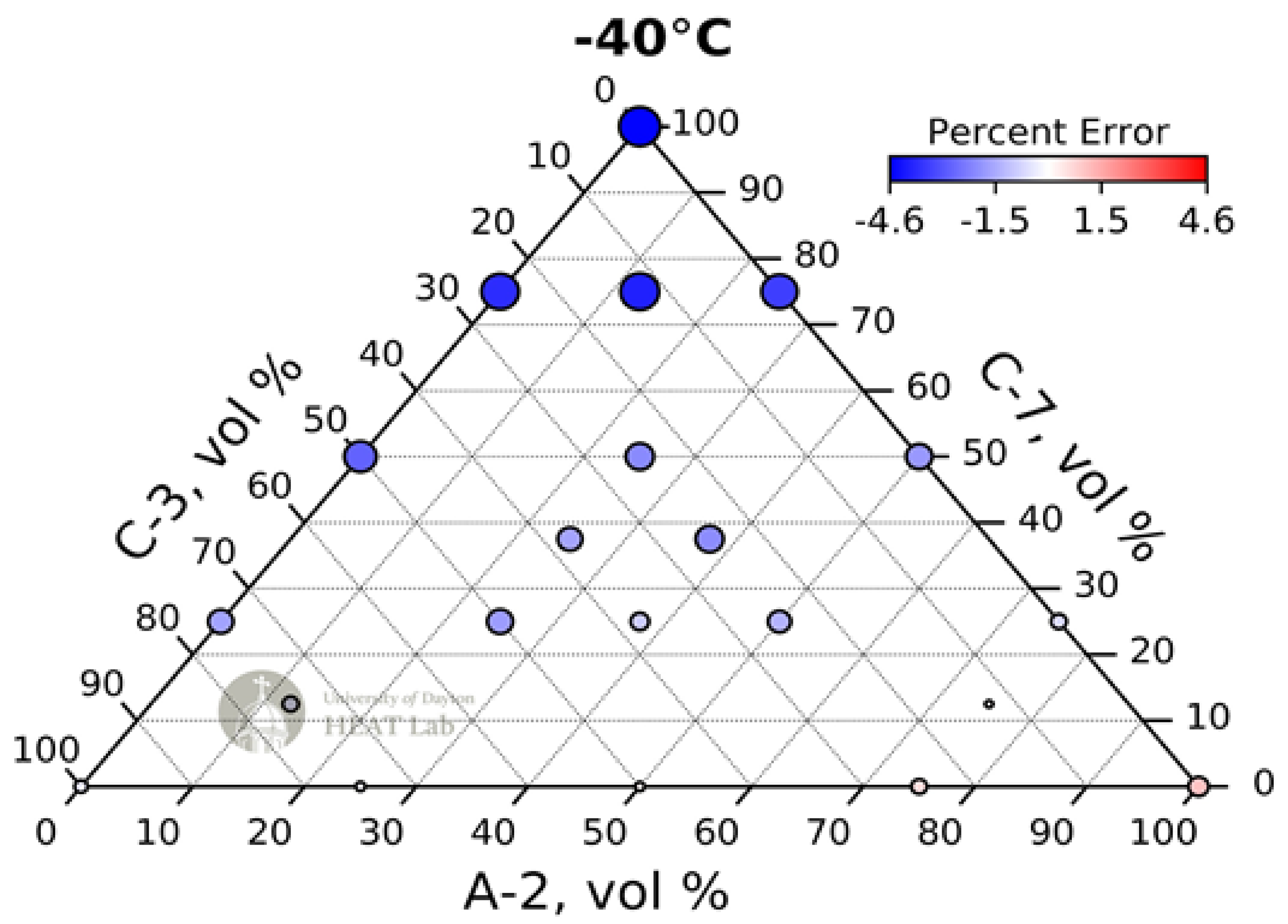
- Arrhenius Blending Rule

$$\log\mu = x_A\log\mu_A + x_B\log\mu_B$$

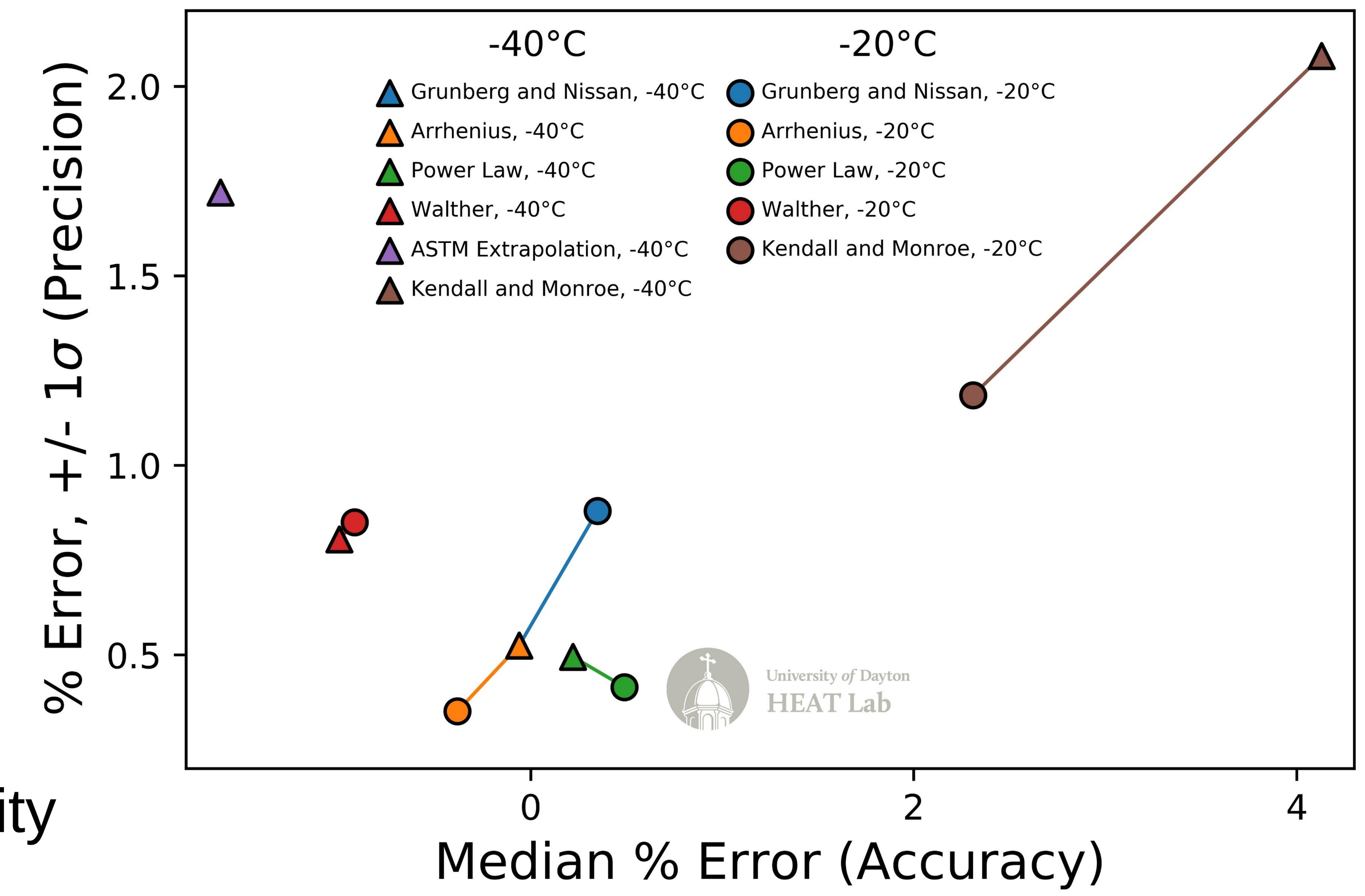
Experiment

- 21 ternary blends of varying component ratios
- Components selected to represent distribution of independent properties that influence viscosity
- Viscosity and density measured over multiple temperatures (-40, -20, -10, 0, and 15 °C)[3]
- Fuel Blend 1: A-2, C-3, C-7
- Fuel Blend 2: C-1, C-8, POSF 12945
- Combination: C-9, HRJ Camelina, Trans-decalin
- Molecule Blend: Hexylbenzene, Methylcyclohexane, Heptamethylnonane

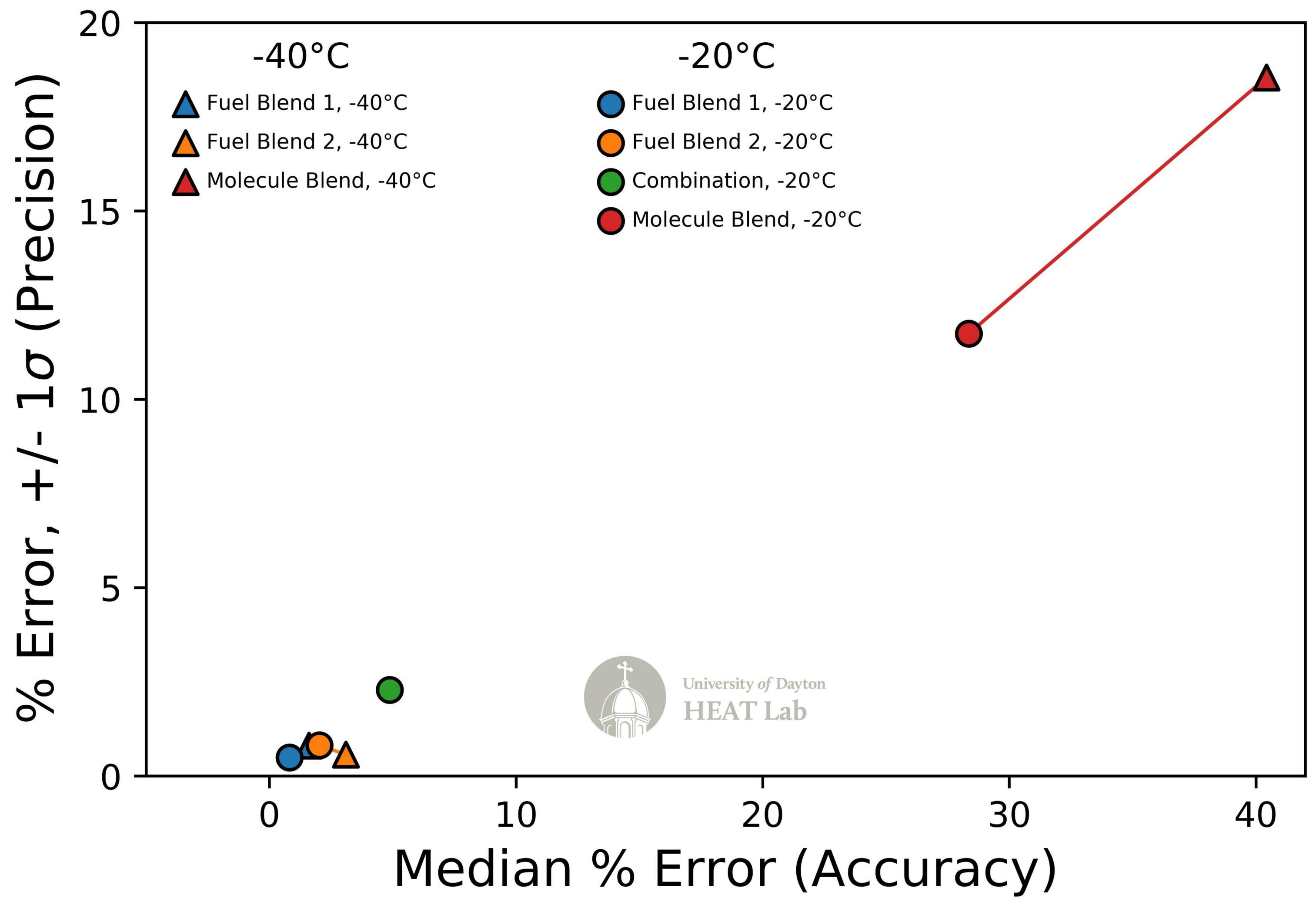
Results



Ternary plot with percent error for extrapolated values of fuel blend 1.



Median and 1σ error ranges for viscosity models applied to fuel blend 1, with models sorted by their median error values.



Median and 1σ error ranges for Arrhenius model applied each ternary blend, with blends sorted by their median error values.

Conclusion and Next Steps

- Arrhenius model the best of the 8 models studied with low median and 1σ error ranges.
- Error grows larger as larger percent of neat molecules are present in blend
- Next steps include using models to blend at higher temperature and then extrapolate down to lower temperatures.
- Also, further study of molecule blends with a focus on the independent properties that influence viscosity (polarity, molecular shape, and molecular size)

Acknowledgments and References

Portions of this work were funded through the Department of Energy (BETO)

1. Joshua Heyne et al., “Sustainable Aviation Fuel Prescreening Tools and Procedures,” *Fuel* 290 (April 15, 2021): 120004.
2. Zhibin Yang et al., “A GC × GC Tier α Combustor Operability Prescreening Method for Sustainable Aviation Fuel Candidates,” *Fuel* 292 (May 15, 2021): 120345
3. Franchesca R Hauck et al., “Experimental Validation of Viscosity Blending Rules and Extrapolation for Sustainable Aviation Fuel,” in *AIAA Propulsion and Energy 2020 Forum*, AIAA Propulsion and Energy Forum (American Institute of Aeronautics and Astronautics, 2020).