Emissions Data Analysis for CLEEN, ACCESS, and Other Recent Tests

Project 24A

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ASCENT
AVIATION SUSTAINABILITY CENTER

Motivation

- Several campaigns have measured black carbon (BC) emissions from gas turbines burning alternative jet fuels and blends of alternative and conventional jet fuels
- Significant reductions in BC emissions (both number and mass) have been observed
- Reductions in BC emissions will result in environmental benefits, both in terms of air quality and climate (reduced BC radiative forcing)

Objectives

- Long-term
  - Improve understanding of how fuel composition influences emissions characteristics

- Near term
  - Gather and analyze non-volatile particulate matter (nvPM) emissions data collected from CLEEN, ACCESS and other recent emission measurement campaigns
  - Develop improved models for the relationship between fuel composition and nvPM emissions, incorporating altitude effects and additional fuel composition information

Outcomes and Practical Applications

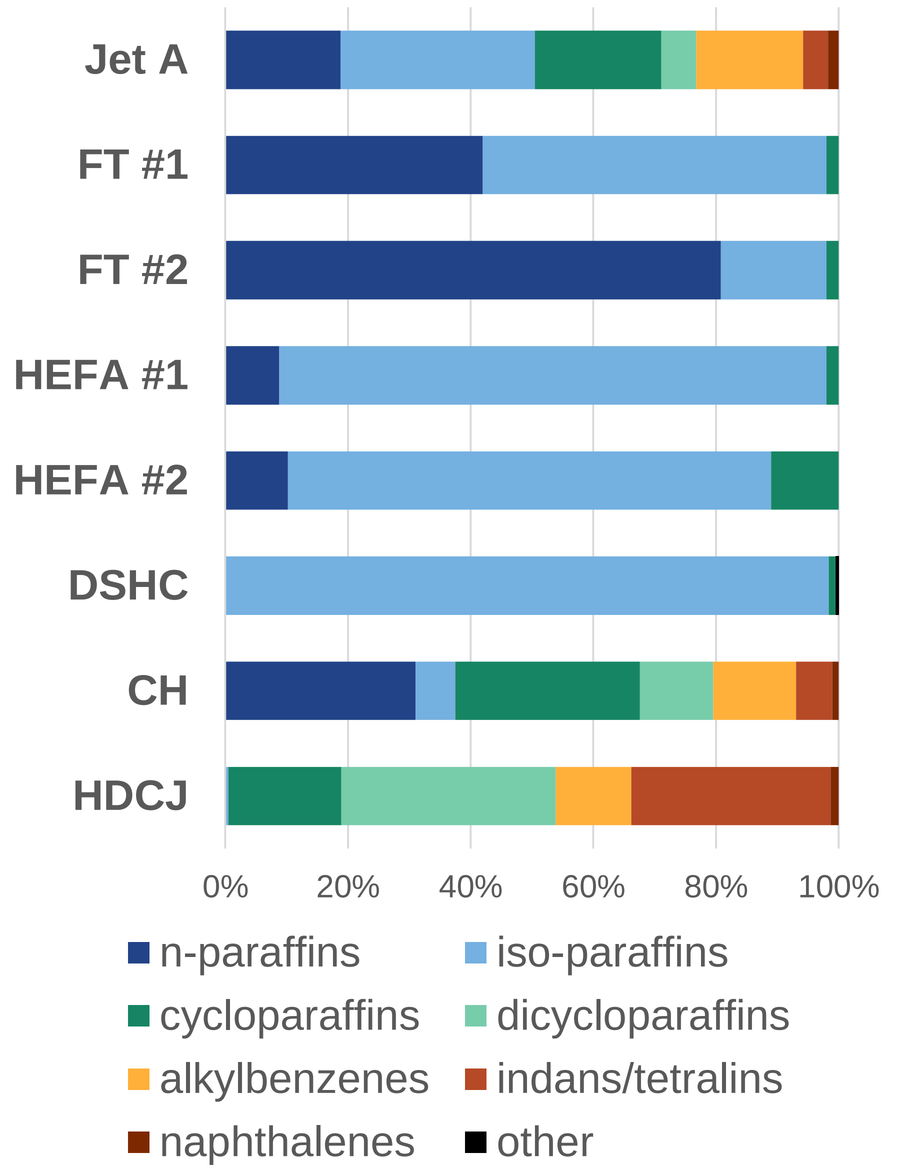
- Outcomes
  - A dataset comprising nvPM and other emissions data from alternative fuel tests
  - A model for predicting nvPM mass and number emissions based on fuel properties and engine operating parameters
- Practical applications
  - Assessment of air quality and climate impacts of using alternative jet fuels

Schedule and Status

Projected Completion	Task / Milestone	Status
November 2014	Gather additional nvPM emissions data from recent measurement campaigns (e.g. CLEEN)	Completed
	Develop database of available emissions measurements and corresponding fuel properties	Completed
March 2015	Update nvPM model to account for altitude effects	Partially completed
August 2015	Extend nvPM model to incorporate results from non-paraffinic alternative fuels	Partially completed

Approach (1 of 2)

- Alternative fuels have different compositions from conventional jet fuels
- Relate fuel composition to observed emissions using chemical kinetics models
- Compare emissions between (blended) alternative fuels and conventional fuels at the same conditions

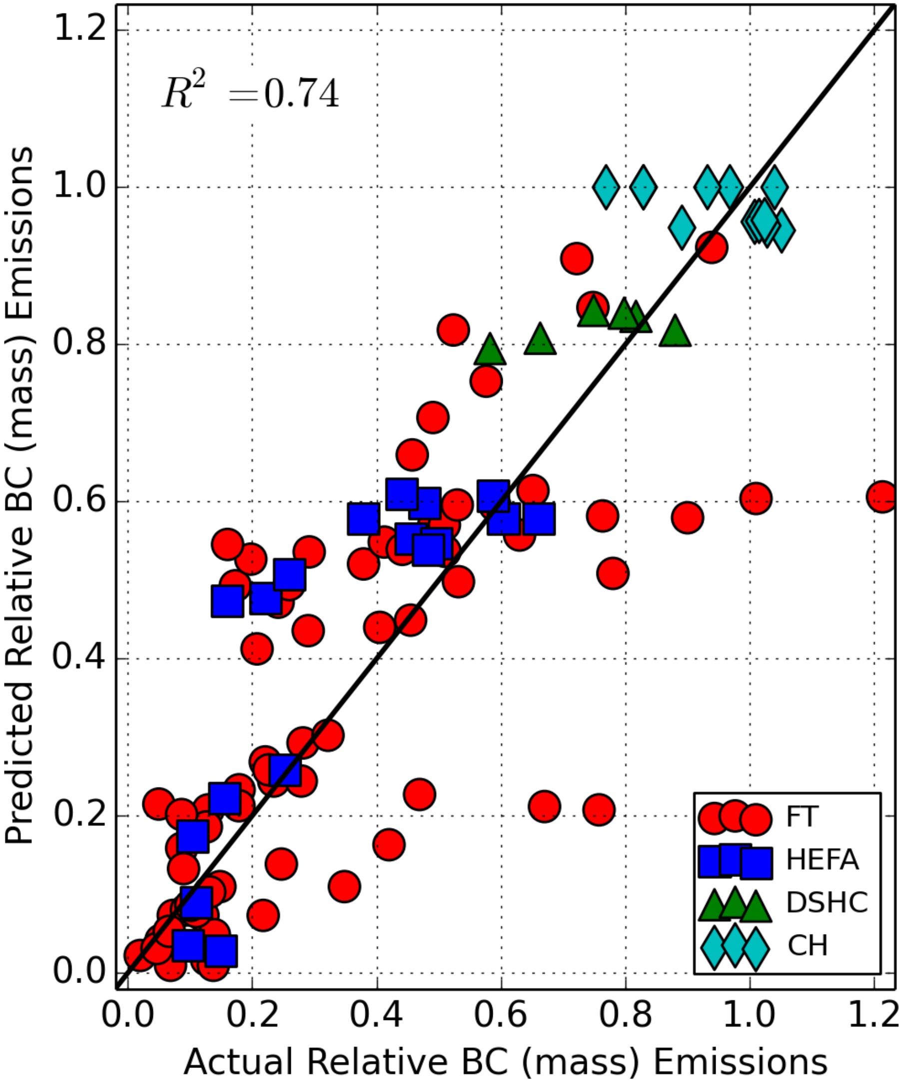


Approach (2 of 2)

- Model for paraffinic fuels
  - Use a simplified model of kinetics for PAH formation & growth to relate relative BC production to fuel properties
  - PAH growth starts with either cyclization of combustion intermediates or existing fuel aromatics
  - Total soot production is the sum of a component independent of fuel composition and a component proportional to fuel aromatics
- Generalized emissions model
  - Use detailed chemical kinetics to predict relative emissions contributions from different fuel components
  - Relative contributions vary with engine operating conditions
  - Total soot production is the weighted sum of contributions from each fuel component

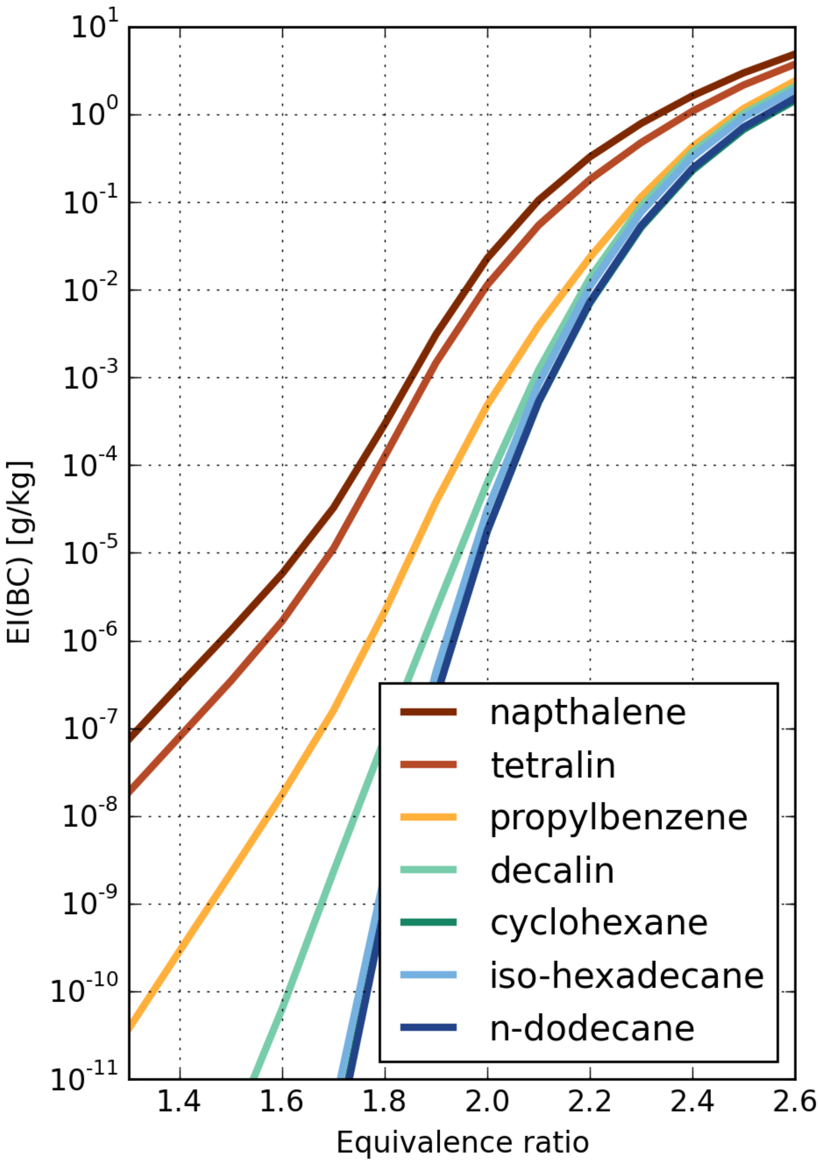
Recent Accomplishments and Contributions (1 of 3)

- ASAF (Approximation for Soot from Alternative Fuels) model developed for FT and HEFA fuels
- DSHC and CH results fit with existing model
- DSHC is a paraffinic fuel, like FT and HEFA
- CH has similar composition to conventional jet fuel, and similar emissions



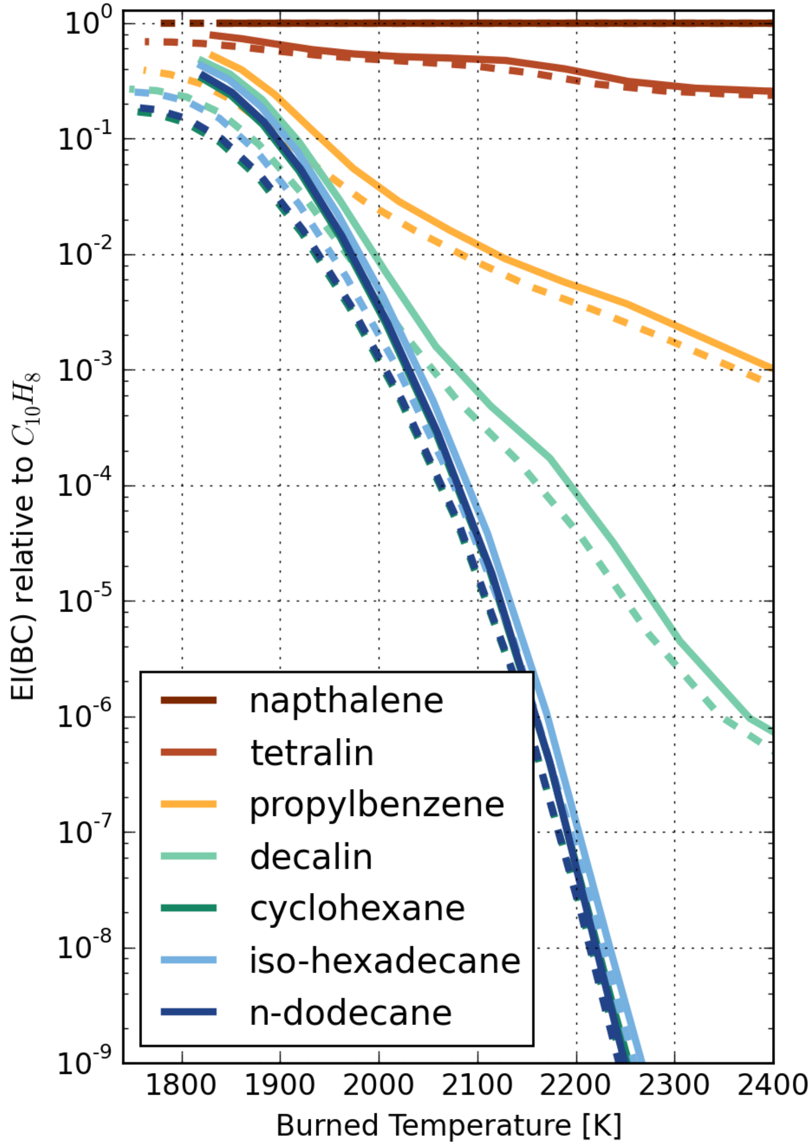
Recent Accomplishments and Contributions (2 of 3)

- Use single zone reactor model with detailed chemical kinetics to predict BC formation
  - Results depend strongly on equivalence ratio
  - Differences between compounds diminish at higher equivalence ratios
- Consistent with the observed behavior for alternative fuels
  - Differences between conventional and alternative fuels decrease at high thrust settings



Recent Accomplishments and Contributions (3 of 3)

- Comparison of sea level static (solid lines) with cruise altitude (dashed lines) conditions
- Plotting relative BC emissions (compared to naphthalene) as a function of flame temperature shows correspondence between the two conditions
- Suggests that ground level, static emissions tests sample the desired parameter space



Interfaces and Communications

- External
  - Work presented at AEC Roadmap Meeting (May 2015)
- Within ASCENT
  - Collaborating with Penn State (ASCENT Project 24B) on creating a shared alternative fuels emissions database, and on using modeling results to assess effects of altitude on nvPM emissions
  - Working with ASCENT Project 20 “Development of NAS wide and Global Rapid Aviation Air Quality” to estimate air quality impacts
  - Working with ASCENT Project 21 “Improving Climate Policy Analysis Tools” to estimate climate impacts

Summary

- BC emissions from alternative fuels depend on engine (combustor) conditions and fuel composition
  - BC emissions from paraffinic alternative fuels can be described as resulting from two mechanisms, one proportional to fuel aromatics
  - Single-parameter correlation works reasonably well for FT, HEFA, CH, and DSHC fuels and blends
- For fuels with more complex compositions, more fuel property information and modeling detail is required
  - Each fuel component has a relative sooting tendency which is a function of combustor conditions
  - Understanding compositional effects requires detailed fuel analyses
  - Further work is needed to map ground-level test data to cruise altitude

References

- Speth R.L., Rojo C., Malina, R. and Barrett S.R.H., "Black carbon emissions reductions from combustion of alternative jet fuels." *Atmospheric Environment* 105, pp. 37-42, 2015. DOI:10.1016/j.atmosenv.2015.01.040
- Speth R.L., Malina, R. and Barrett S.R.H., "Effects of fuel composition on particulate matter emissions." Aviation Emissions Characterization Roadmap Meeting. Washington, DC. May 19, 2015.

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