ASCENT Project 48

Analysis to Support the Development of an Engine nvPM Emissions Standards

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Objective:

ICAO-CAEP has worked to develop new nvPM standard over last 5 years. FAA is a key contributor to this process. This project supports FAA's decision making by providing technical analyses related to nvPM emissions and the costs and benefits of regulating these emissions.

Project Benefits:

The analyses produced in this project provide FAA with a rigorous scientific basis to inform decisions related to the nvPM standard and promote an efficient implementation process that provides industry with regulatory certainty.

Research Approach:

To implement the nvPM standard, we focus on:

- Developing a method to predict nvPM mass and number emissions
- Generating candidate stringency options
- Conducting an environment cost-benefit
- Develop "no-change" emissions criteria to decide engine re-measurements
- Identify margins to current nvPM standard

Major Accomplishments (to date):

- Novel approach to predict nvPM emissions published in ES&T (Agarwal et al., 2018)
- Cost-benefit analysis for all nvPM options
- Analyses are regularly presented to ICAO-CAEP during teleconferences and meetings of CAEP-WG3

Future Work / Schedule:

Continuing work to support FAA decision making. Next focus is on relating the benefit of ground-based emissions regulations with cruise emissions

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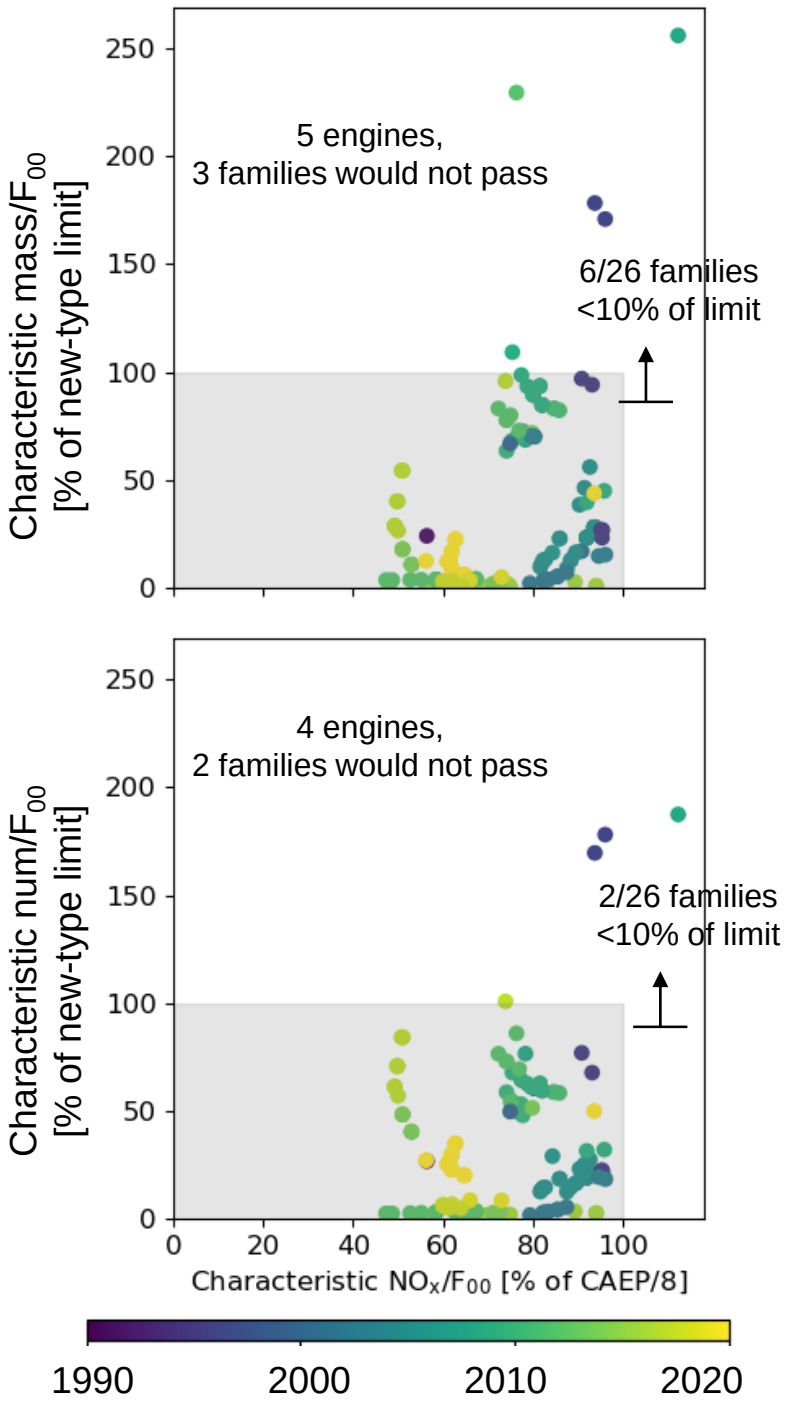
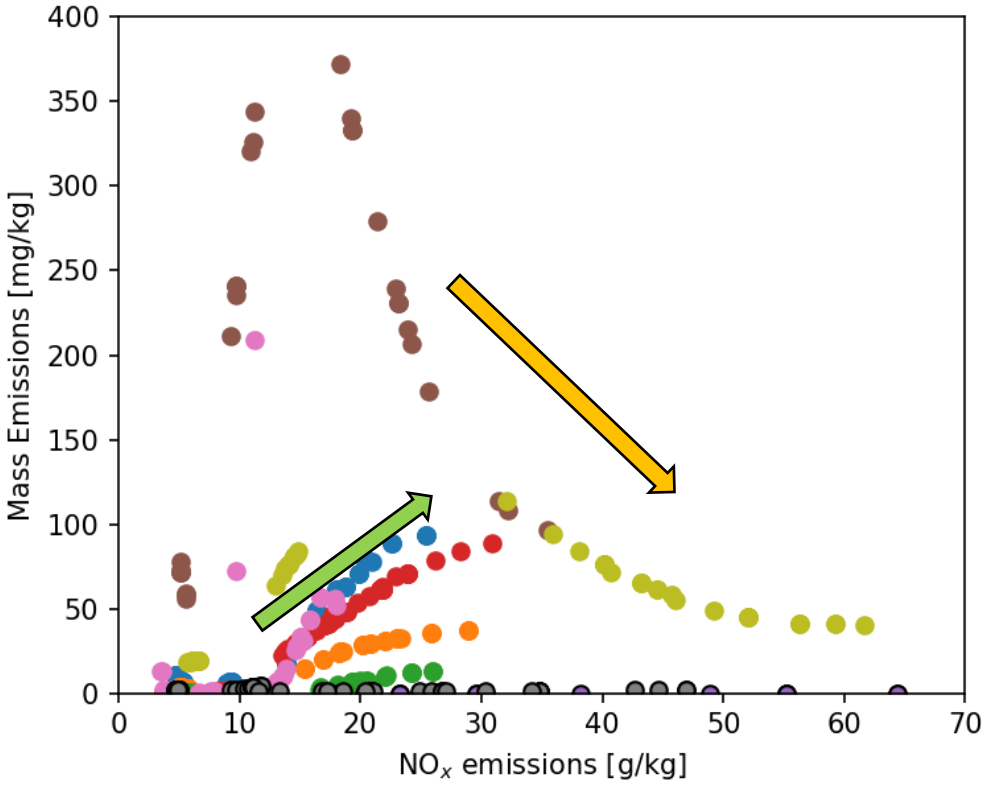
Evolution of CAEP nvPM regulations

- CAEP/10 (2016) introduced max. mass conc. standard and a new certification (01/01/2020)
  - nvPM data now publicly available
- CAEP/11 (2019) regulation on LTO emissions over rated thrust (F_{00})
  - Applicable from 01/01/2023
  - Margin to new-type standard
  - Expect emission trade-offs
- Study trends/margins
  - 2-3 older families above new-type
  - NOx margins between 50 – 90%, but nvPM from 0%+



NO_x – nvPM relationship in a single family not always clear

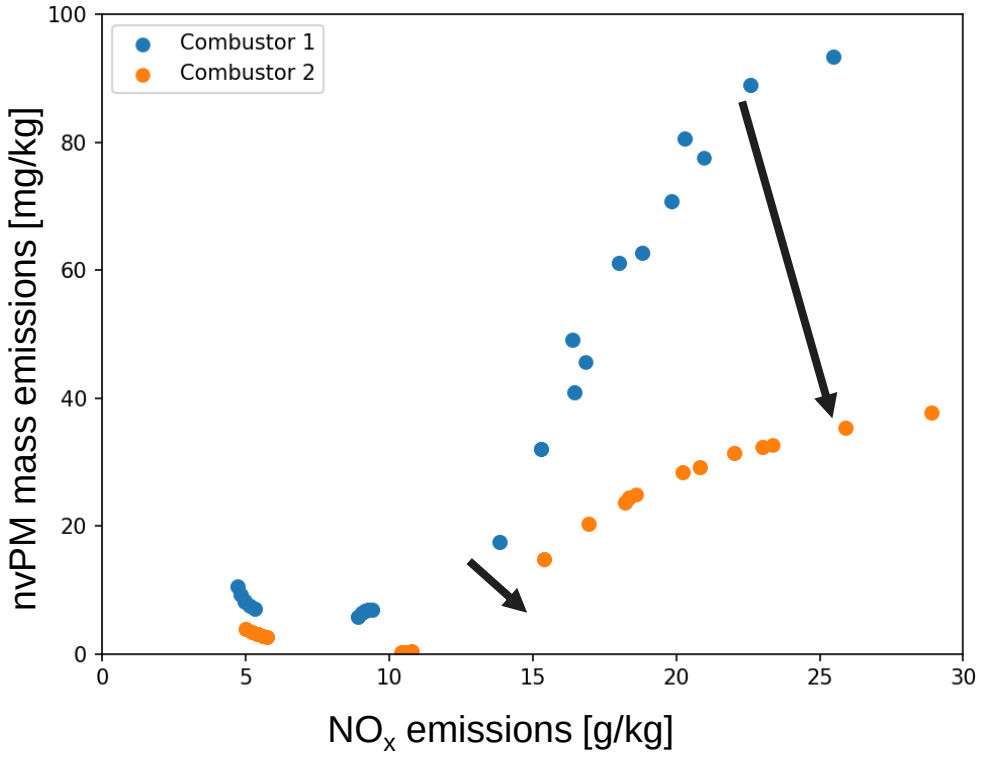
- Group engines by family and study NO_x – nvPM relationship
- For all engines, higher thrust means more NO_x emissions
  - Generally, this is true for nvPM mass emissions
  - nvPM emissions have peak at mid-thrust and then decrease above



Each color represents emissions from a single engine family

NO_x – nvPM response to combustor change

- Same engine with change to combustor
  - "Natural" experiment to test combustor response
  - Expect mass emissions to decrease for NO_x increase
- Shows expected trade-off between NO_x and EI_m
  - 1.05 – 1.15x NO_x increase causes 1.2 – 25.0x EI_m drop
- NO_x penalty important given current margins
  - Potential to optimize



Summary

- Looked at margins of current engines to NO_x and nvPM regulations
  - 2-3 engines would not pass new-type standard
  - Most families have margin of above 10%
- Aimed to identify relationship between NO_x and nvPM emissions
  - Within family, relationship is not clear
  - Found 1 family with combustor change
    - Showed a NO_x penalty (up to 1.15x) for nvPM reduction (up to 25x)
- Other factors to consider
  - Mixed versus unmixed engines
  - Engine size and combustor design age