

Certification versus research measurements: Investigating the variability of particle emissions of large jet engines from a long-running series of emission tests



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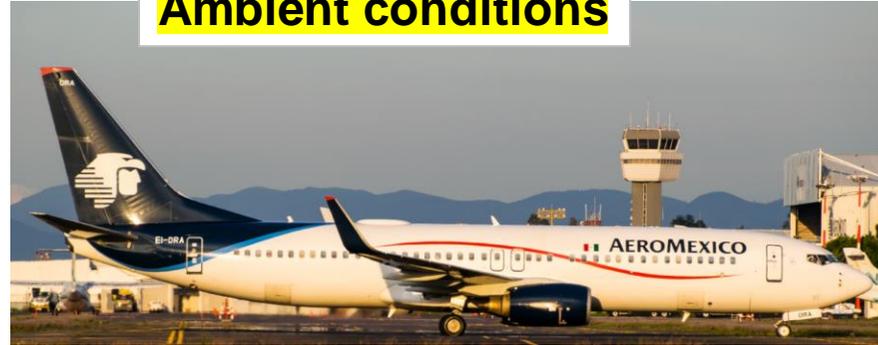
- SR Technics Switzerland AG – engine test cell access, engine performance data and technical support (Mr. Frithjof Siegerist)

Major sources of nonvolatile PM emissions variability in emission tests of a given engine type

fuel composition



Ambient conditions



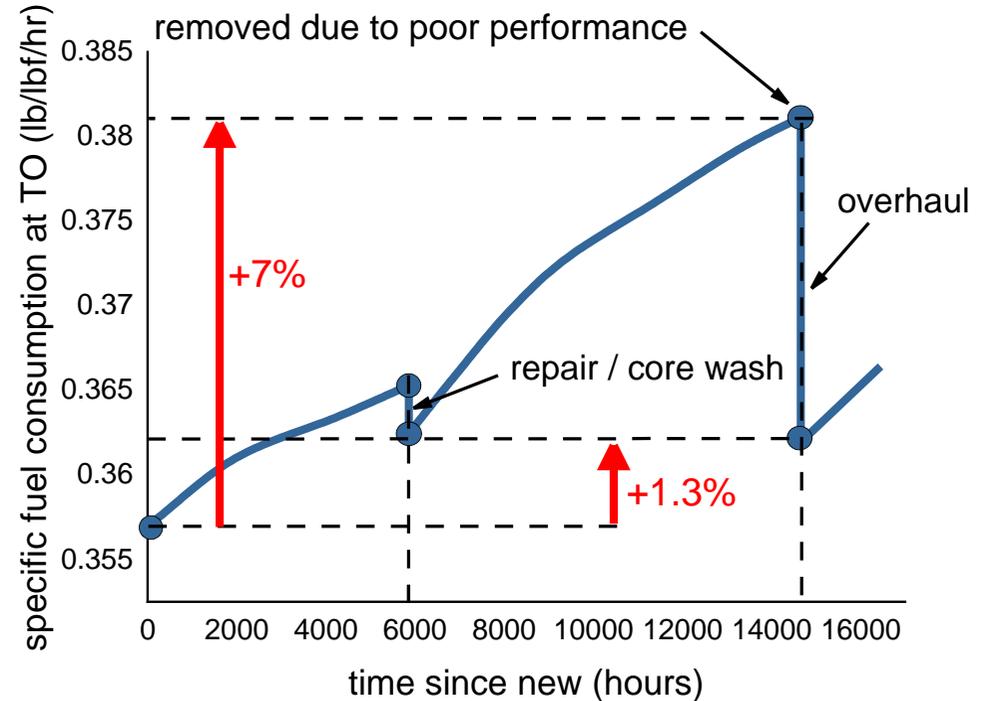
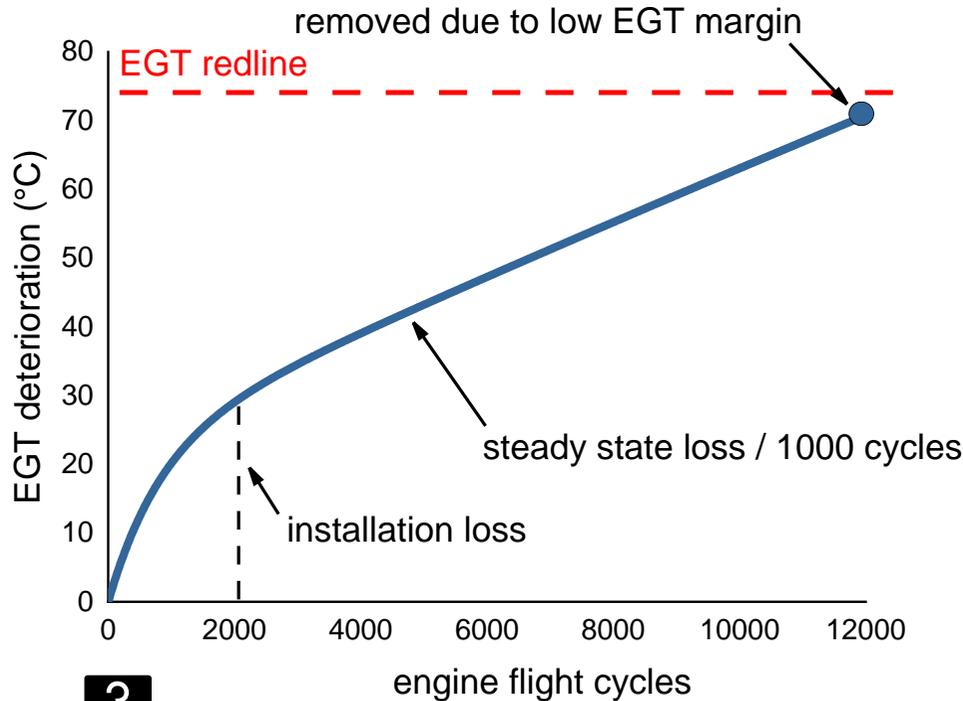
sampling and measurement



engine-to-engine variability & engine history



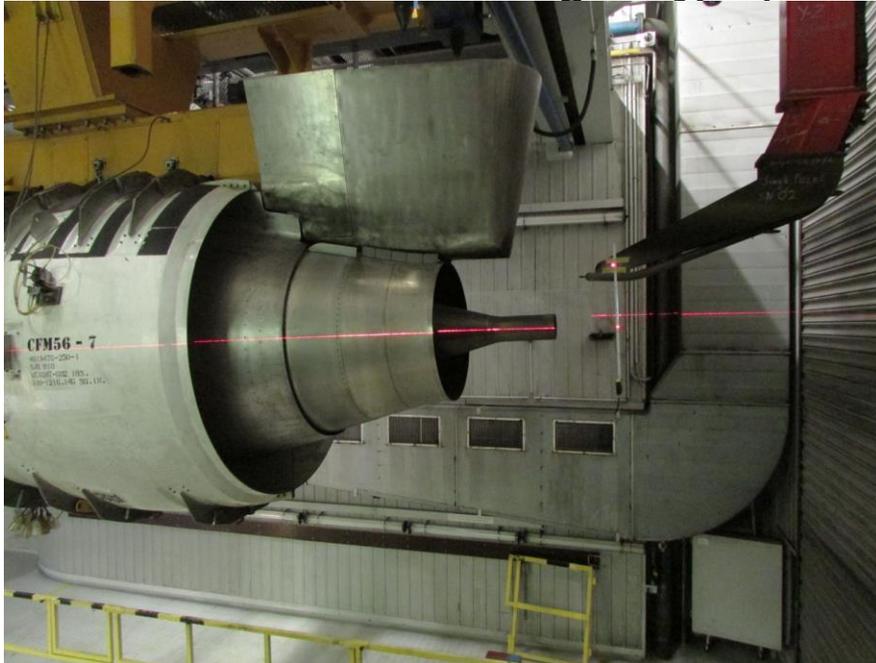
Engine performance deteriorates with increasing time in service until a performance restoration is required



How do PM emissions change over time and after an overhaul?

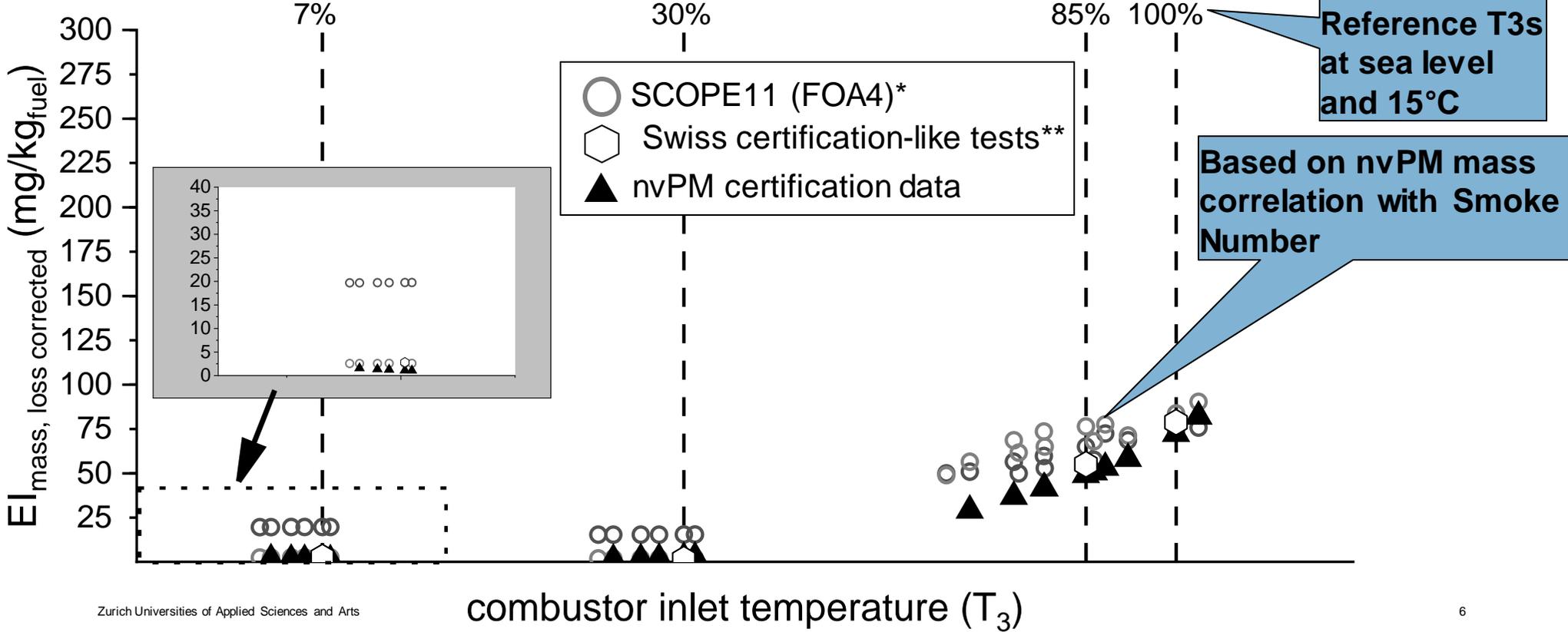
Goal: Improve nvPM emission models with data for in-service engines – need to correct for engine age?

- Emission tests in a test cell during pass-off tests of repaired and overhauled engines
- ICAO Annex 16 Vol. II compliant system (except for the current exhaust probe)
- **Here we focus on one engine type (16 engines tested, two combustor versions)**



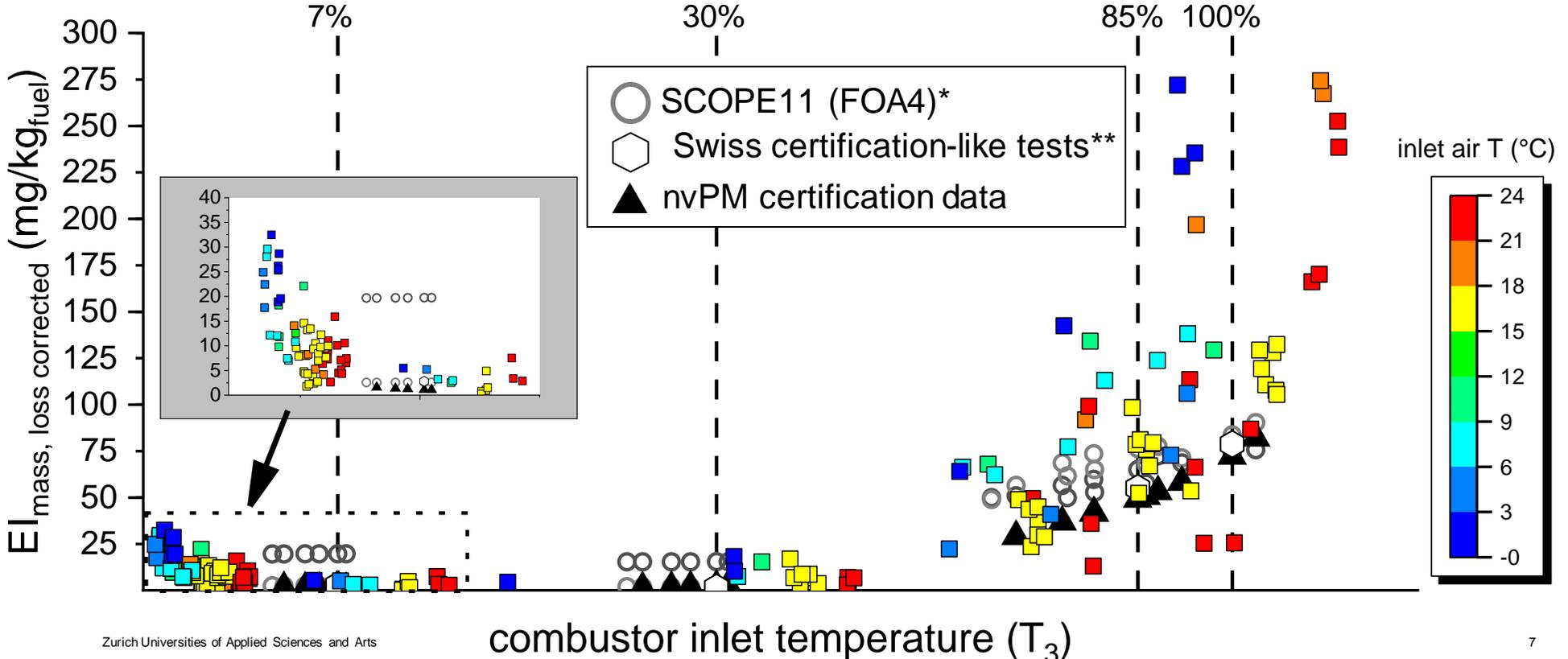
nvPM mass emission index at the engine exit (particle loss-corrected)

GMD increase from 10 to 40 nm
ICAO landing and take-off thrust modes for a common thrust rating



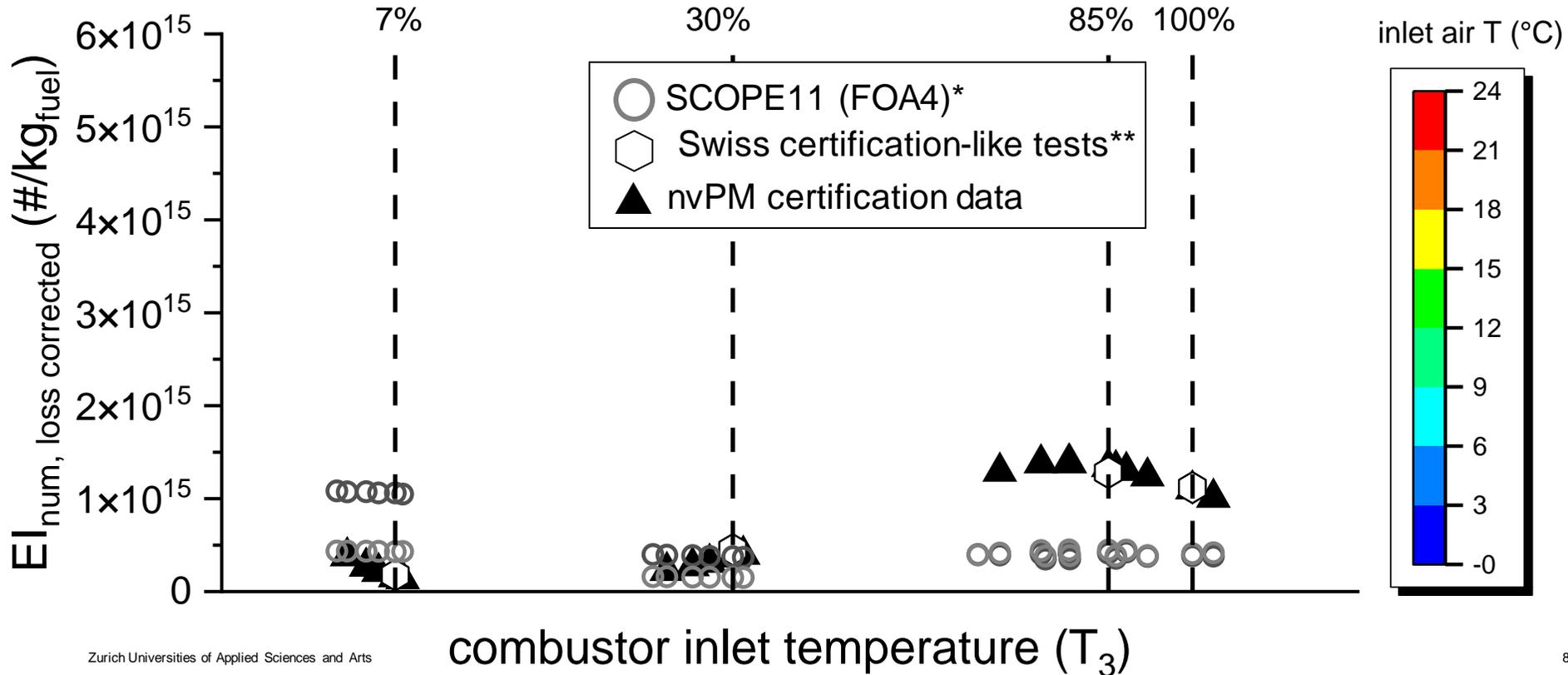
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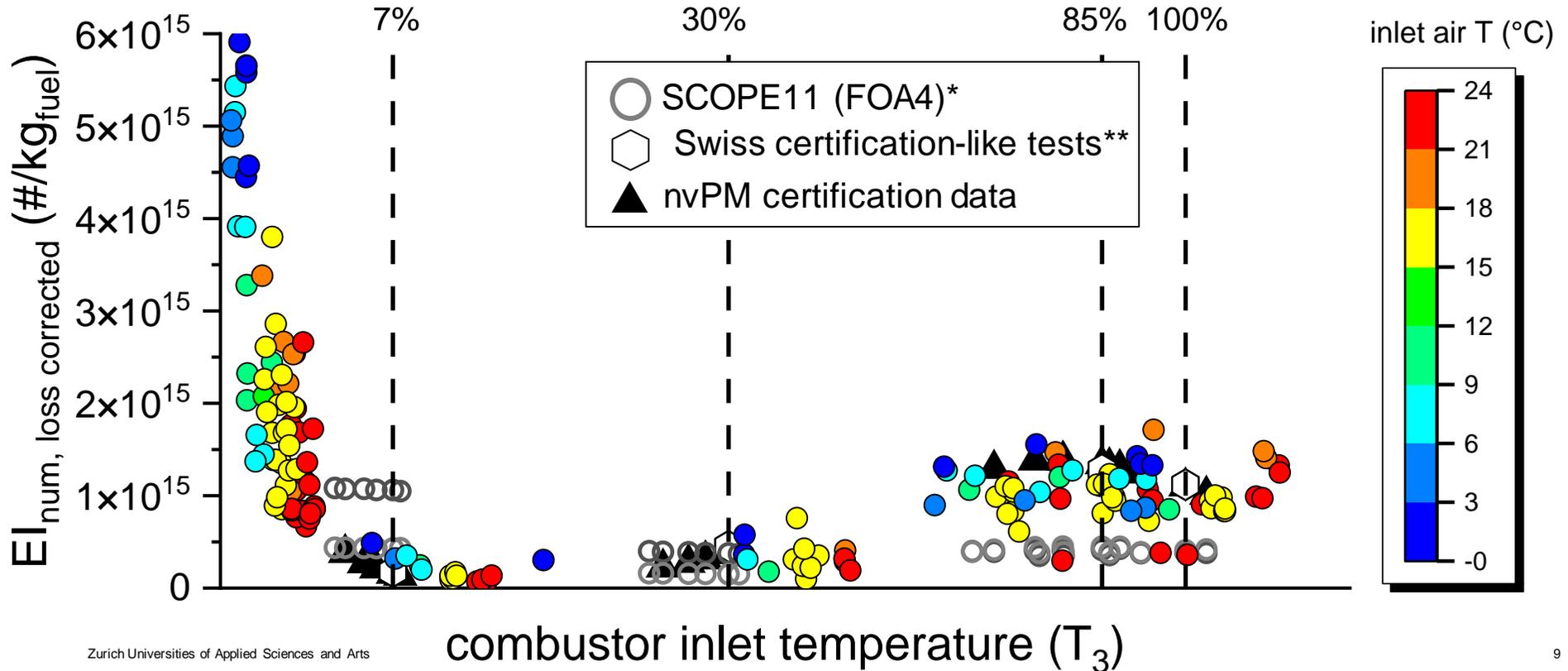
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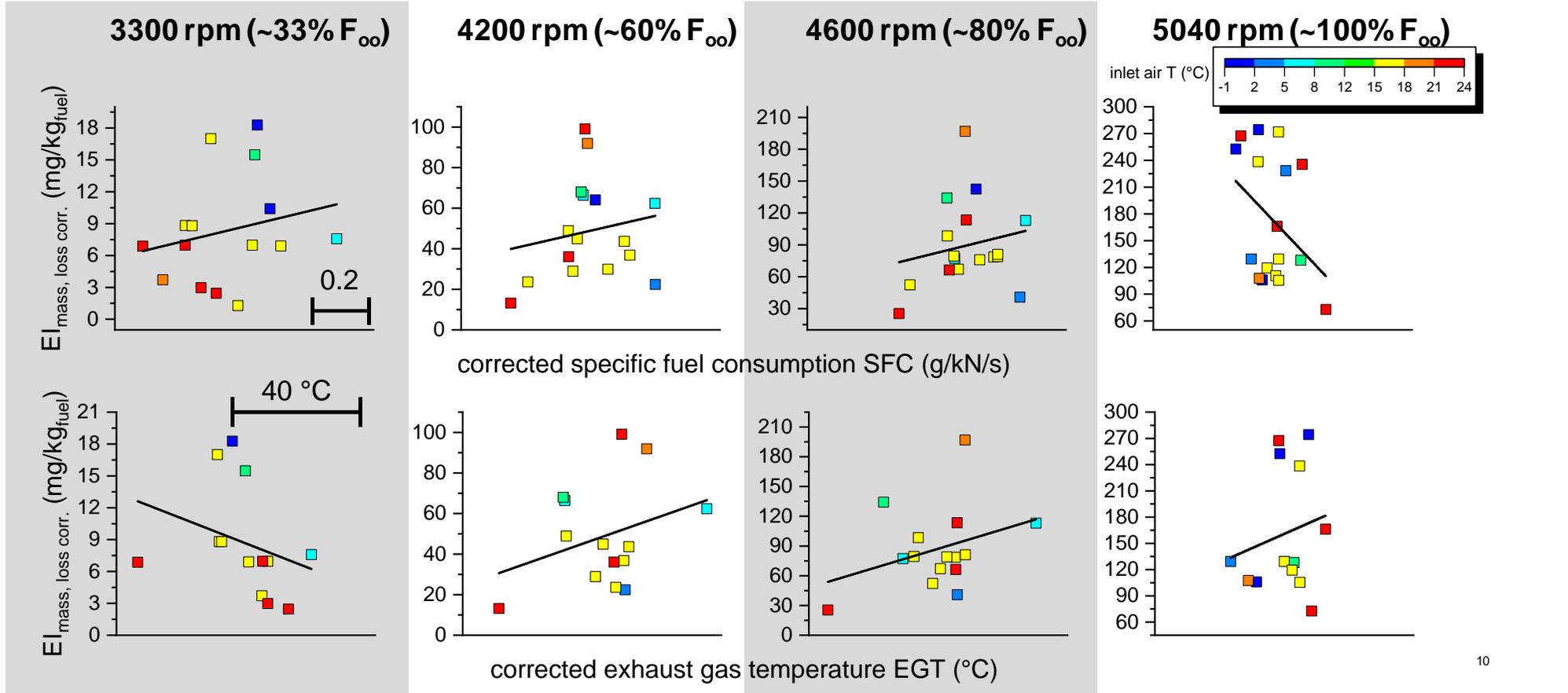
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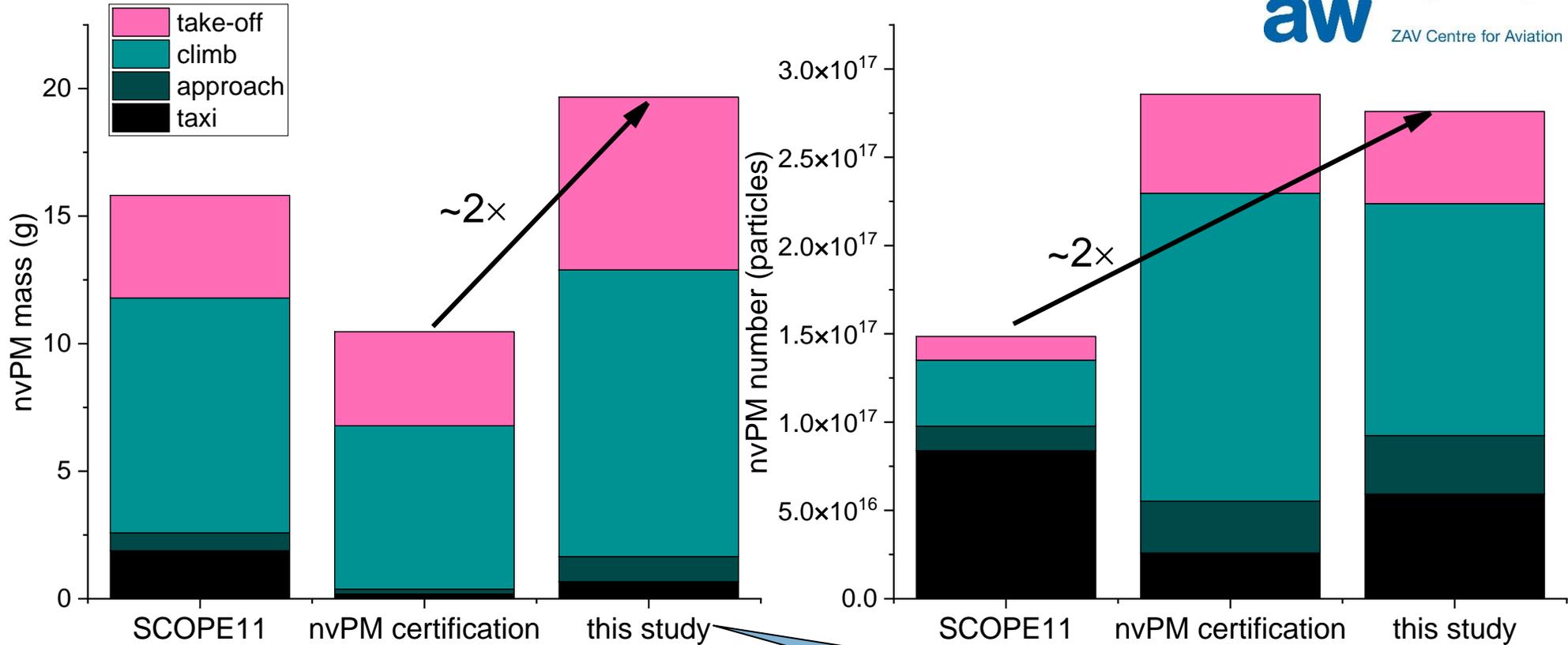


EI mass as a function of fuel burn (SFC) and EGT at a given corrected fan speed (N1)

Poor correlation with EI mass for the ensemble of engines tested



nvPM mass and number emissions from the standardized landing and take-off (LTO) cycle



Mean values for the 16 engines tested after repair / overhaul

Summary

- nvPM emissions at <7% thrust varied by an order of magnitude and increased with decreasing ambient temperature. *Are we neglecting idle emissions?*
- High thrust nvPM mass emissions of in-service engines (even after an overhaul) tend to be higher than certified emissions, leading to higher emissions in the LTO cycle and likely also at cruise.
- LTO nvPM number emissions were in good agreement with certification for the engine type investigated. SCOPE11 tends to underestimate nvPM number.
- Excess nvPM mass did not correlate with SFC and EGT margin for the ensemble of engines. *Future work: sensitivity study and test of a single engine before/after overhaul and study gaseous emissions.*