

CAAFI Webinar Series
Virtual Web Meeting
4 June 2025



Volatile PM emissions: SAF & Fuel composition effects

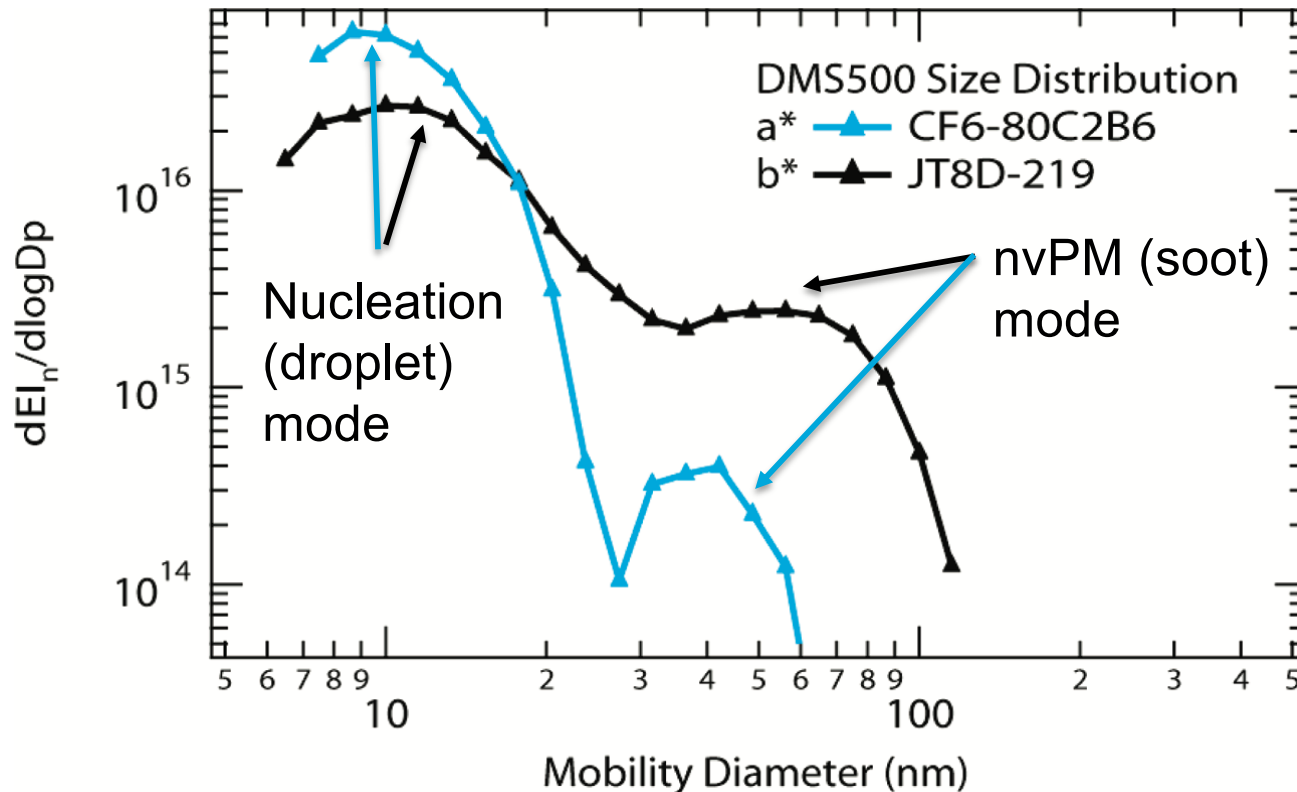
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Sustainable Aviation Fuels

- ◆ Bio-sourced fuels (SAFs) a major interest for commercial aviation: help mitigate CO₂ footprint
- ◆ Have found SAFs can decrease soot (nvPM) significantly (cleaner burning)
 - Local Air Quality benefits
 - Less soot for contrail formation: does this affect contrails' radiative forcing?
 - Due to decrease in aromatic species in fuel
 - *similar gains could be obtained with fossil fuel of same composition*
- ◆ May also affect vPM (and gaseous pollutants) emissions . . . Impacts of vanishing FSC?

Volatile particles add to soot downstream



from: Herndon et al., *Env. Sci. Technol.* **2008**, 42, 1877–1883, 26 - 29 September 2004, MS&T (UMR) measurements at Hartsfield-Jackson International Airport, *with annotation added*.

- ◆ Advected plumes at airport (100s of m)
- ◆ Bimodal distributions indicate both soot mode and a smaller mode
- ◆ Smaller mode can be 1 to 2 orders of magnitude more numerous than soot mode
- ◆ Many additional engine and airport studies

Importance of volatiles in total PM

- ◆ Volatile PM contributions to the various PM modes:
 - newly formed volatile particles (smallest mode: nucleation mode)
 - condensed species on soot surfaces
 - oil mode (sometimes a separate, larger mode)
- ◆ Species involved:
 - H_2SO_4 (with water)
 - Organic species due to incomplete combustion
 - some raw fuel (at idle)
 - partially oxidized HCs
 - pyrolytic species, other HCs, etc.
 - oil vapors and droplets emitted from oil system vent
- ◆ Aerosol Mass Spectrometer (AMS) sees **Aerosol Composition**:
 - oil mode (when present: some engines vaporize the oil when venting)
 - soot coating composition (organics, sulfate)
 - nucleation mode usually too small for AMS to see

Gulfstream G700 SAF 2024 ground test



Gulfstream Photo Credit

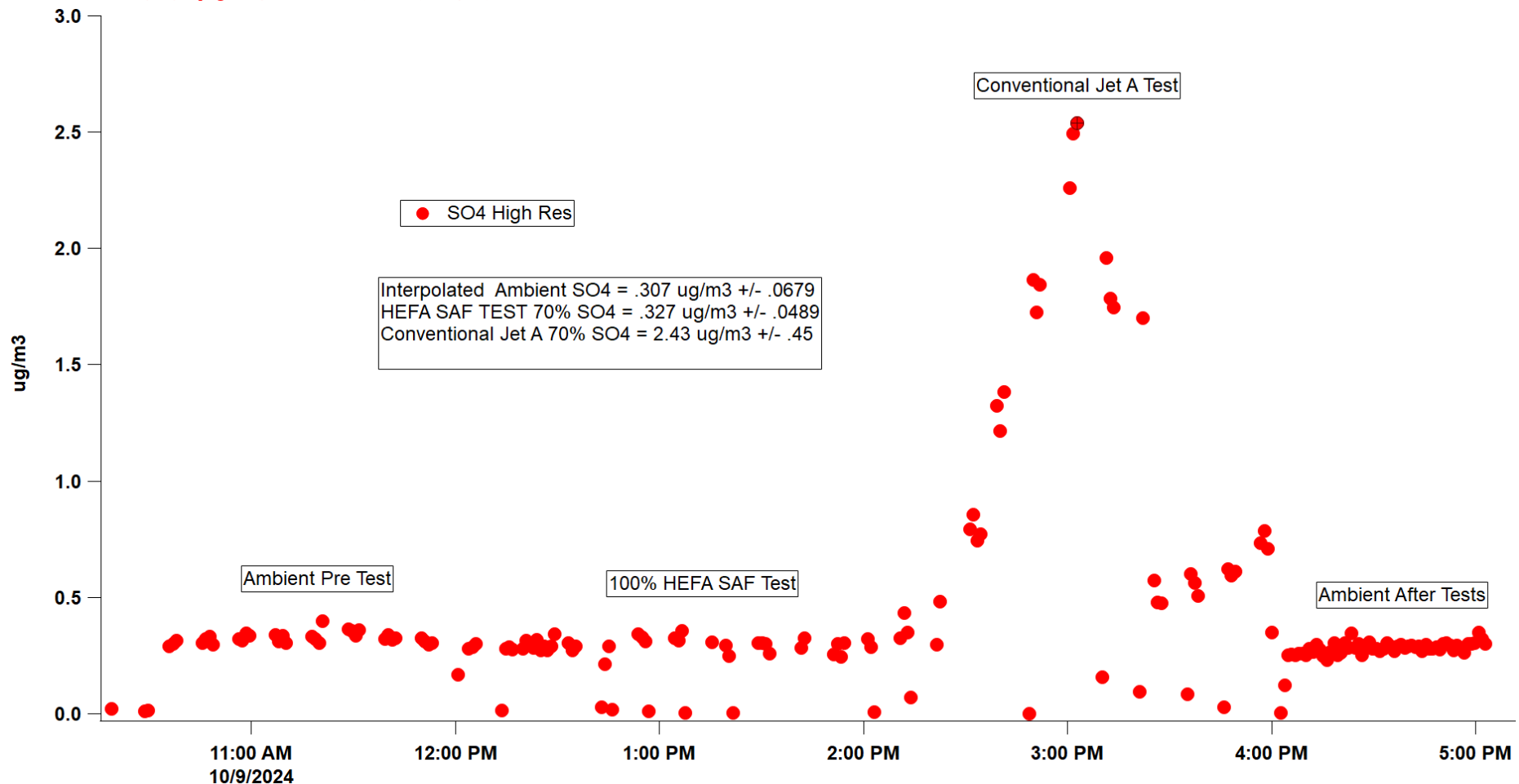
Gulfstream G700 SAF 2024 ground test



- ◆ Aerodyne, MS&T, FAA, NASA, Colorado State, Rolls Royce (Germany), Gulfstream Team
 - Press release, 31 October 2024:
<https://www.gulfstreamnews.com/en/news>
- ◆ World Energy, World Fuel Services for HEFA SAF
- ◆ 3 Fuels: 100% SAF; 30%SAF/70%JetA; JetA
 - Rolls Royce Pearl 700 engine, sampled at ~ 21 m
 - minimal to **no sulfur contamination** of 100% SAF
 - potential of 100% neat SAF for improving local air quality near airports
 - possible benefits of reducing the formation of condensation trails.
- ◆ Also deflected/redirected oil vent flow to minimize oil contributions to exhaust emissions (not discussed here)

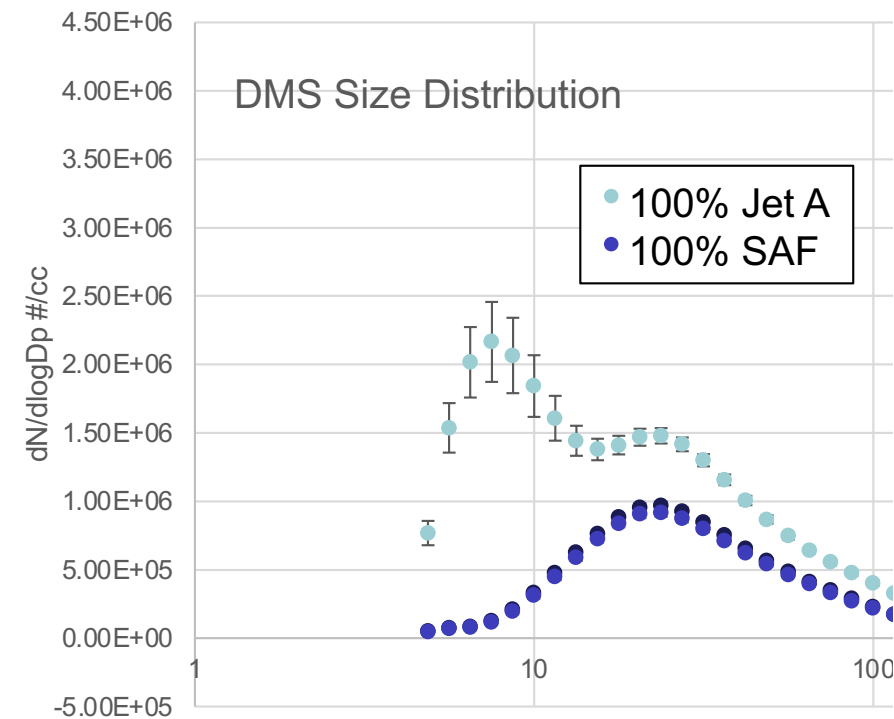
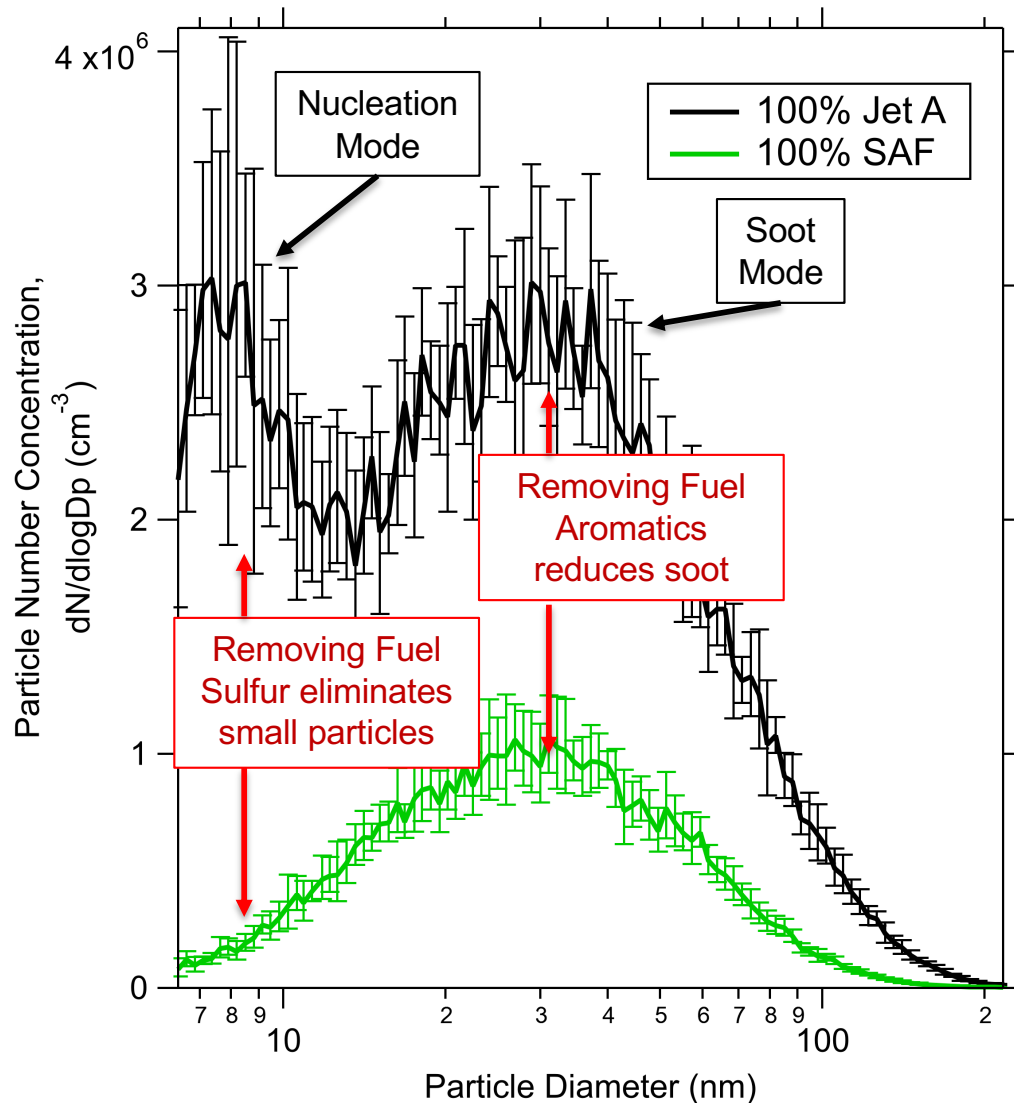
Sulfur on soot is gone with $S \rightarrow 0$

AMS high-resolution SO_4 time series from Day 1 Test:
100% SAF and Jet A



Gulfstream G700 SAF 2024 ground test

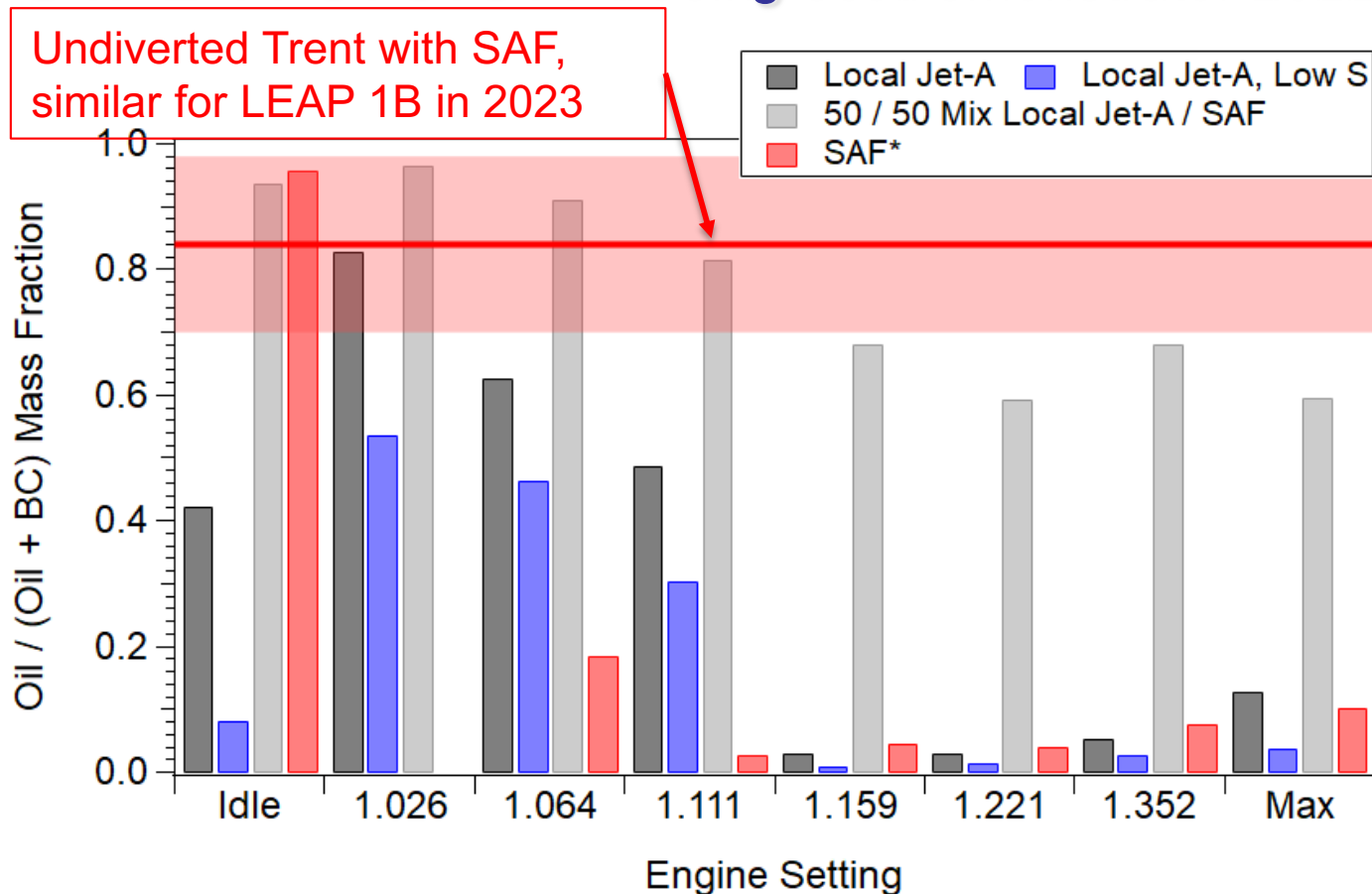
Nucleation Mode is gone with $S \rightarrow 0$



- ◆ Nucleation mode accounts for most particles at >100 nm downstream
- ◆ Major change in microphysics: new particles are not formed
- ◆ If no nucleation, what are implications for soot activation for contrails?

Gulfstream G700 SAF 2024 ground test

Oil Diversion Boeing ecoDemonstrator 2022



- Oil mass comparable to BC mass emissions with no oil diversion
- Oil is a major emission that is not currently regulated

- ◆ Oil diversion using long hose attached to vent tube of Trent engine
 - 50/50 Mix: no diversion
 - Other fuels: Varying success, with best diversion at higher powers with engine powers balanced
 - Room for improvement in future tests

Summary

- ◆ Oil is a major contribution to vPM in aircraft exhaust
 - Currently not controlled or regulated as an emission
 - Useful to look at combustion emissions with oil diverted/redirected
- ◆ Sulfur in fuel causes emissions of H_2SO_4
 - H_2SO_4 can be observed on soot particles* with few ppmm FSC
 - In Gulfstream tests, removed effect of H_2SO_4 nucleation, demonstrating that H_2SO_4 is needed for new particle formation in engine plume → show for other engines, other oil systems, other T, r.h., etc.
 - Possible implications for soot activation: Can low enough H_2SO_4 preclude soot contrail activation? → test contrail properties for this low fuel sulfur level . . . and find way to quantify low S levels
- ◆ Decreasing fuel sulfur (well below [?] 1 ppmm) and oil emissions could dramatically reduce vPM emissions around airports

* depending on soot concentration and background sulfate levels

**Not only, then, in
the world of art,
but equally in the
realm of science,
is Nature our best
teacher.**

Karl Blossfeldt, 1932

