

Biofuels Take Flight: How Advanced Jet Fuels Reduce Cloudiness and Aviation's Climate Impact



Richard Moore

*Langley Aerosol Research Group (LARGE)
Science Directorate, NASA Langley Research Center*

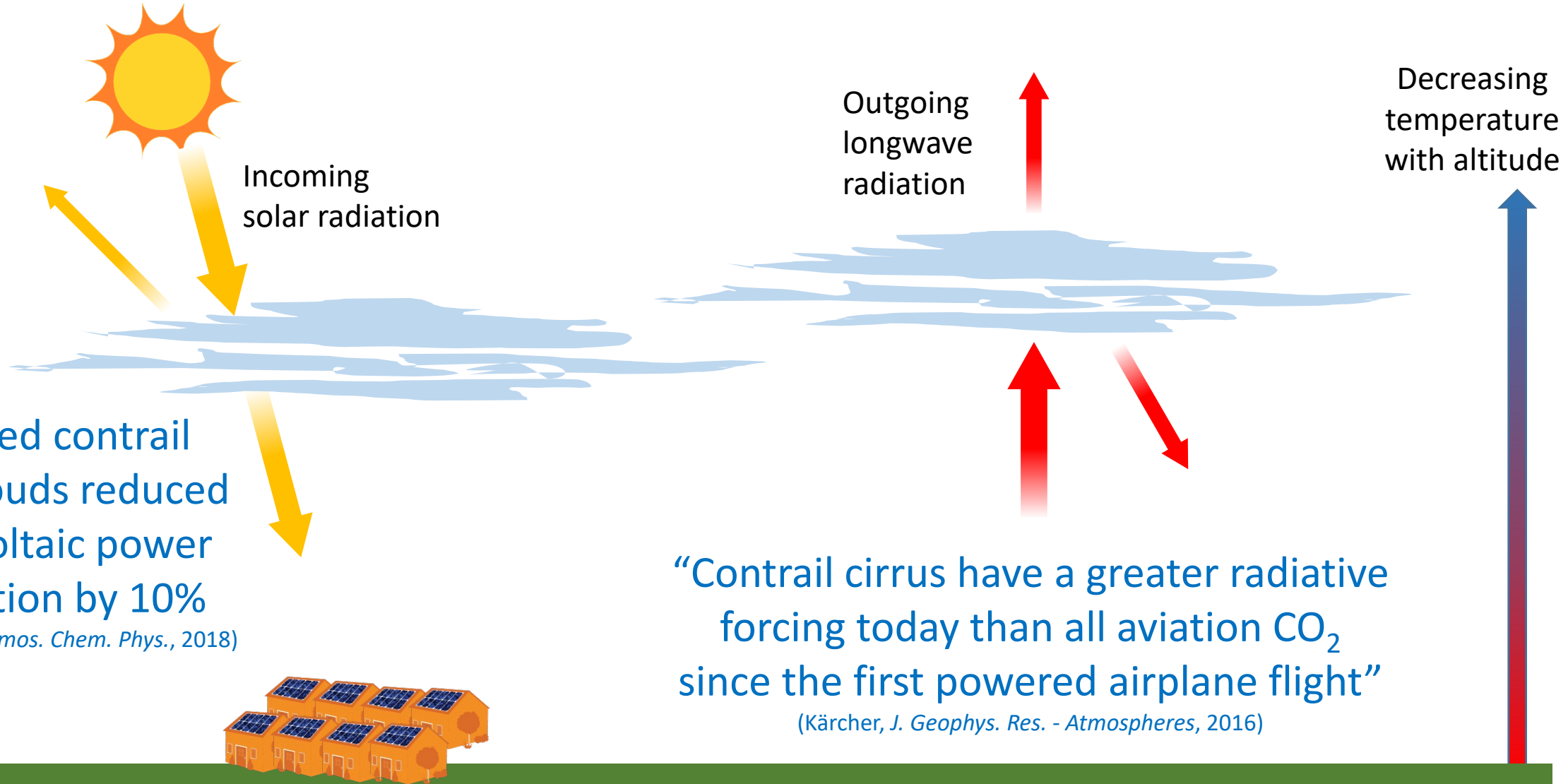
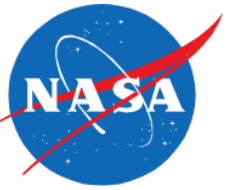


NASA
BY THE PINT

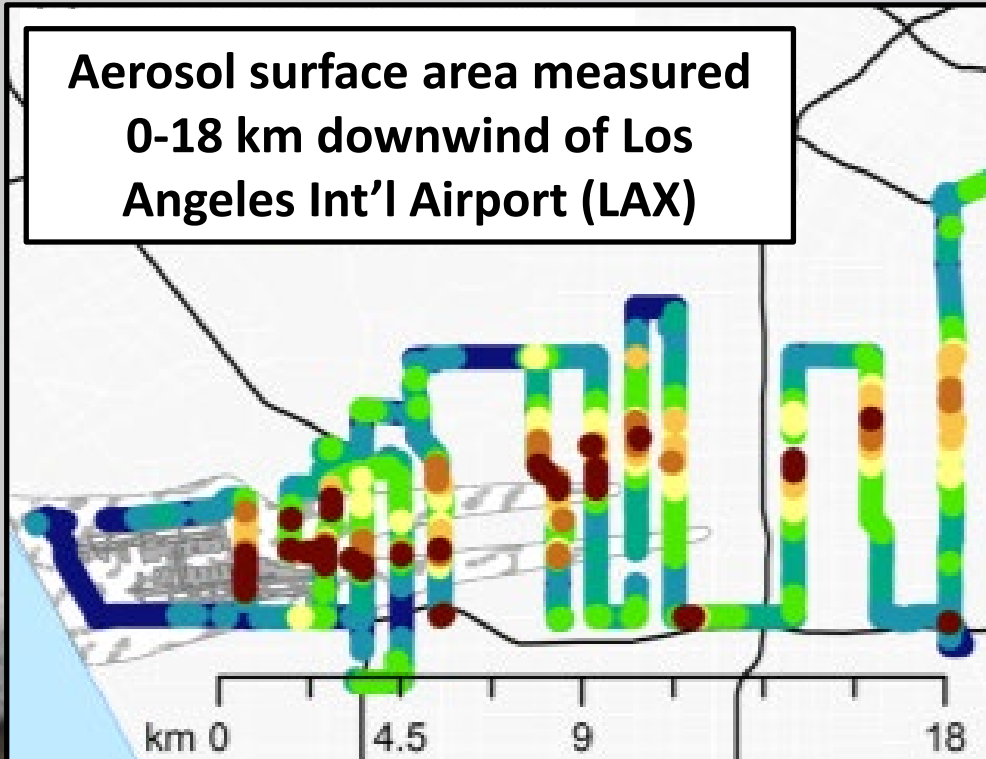
25 February 2020



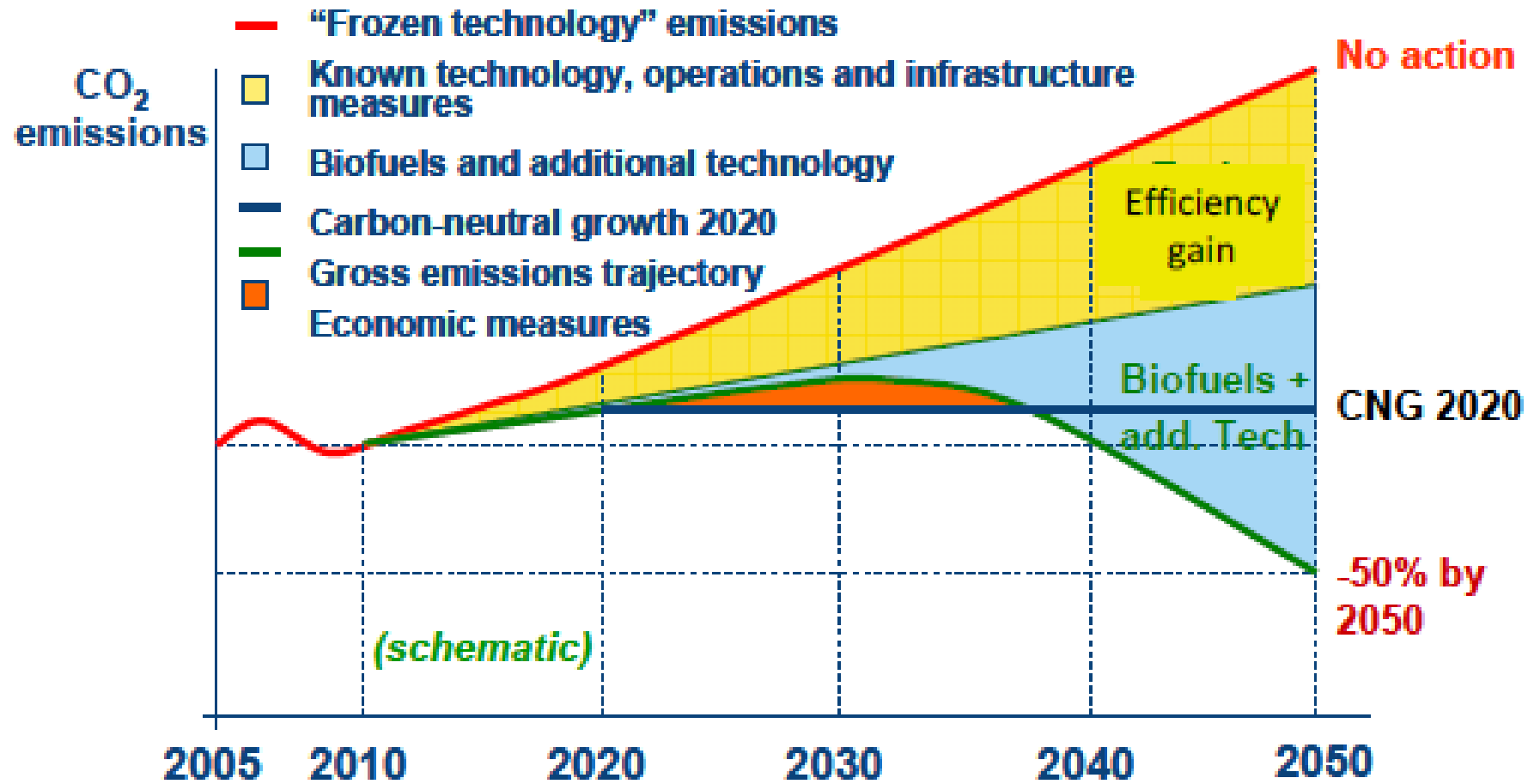
Why would society care about aviation contrail cirrus clouds?



Aircraft emissions affect air quality downwind of airports, which can have adverse health impacts on society and the local population

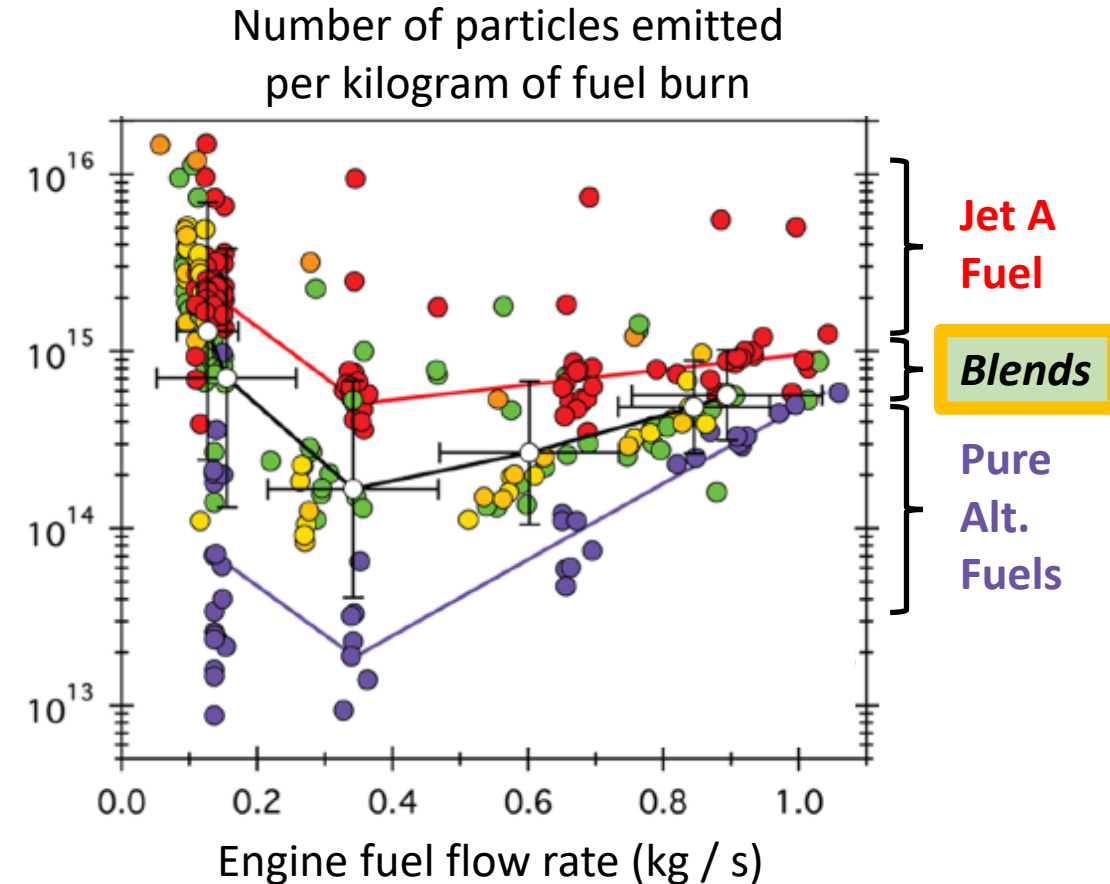
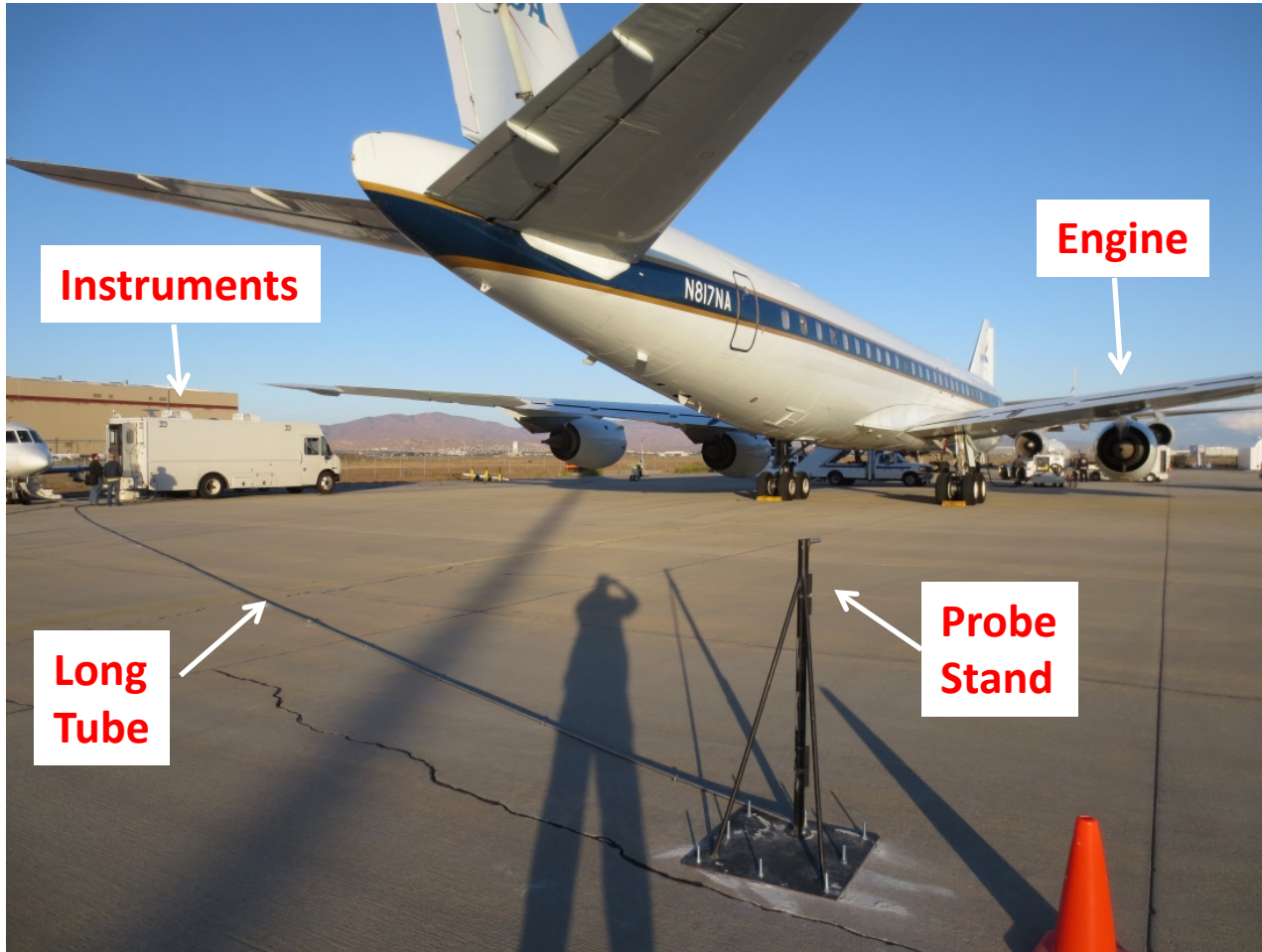


These environmental effects will only increase in the future, as air travel continues to grow at a rate of 2-3% per year.



Source IATA

Ground tests with the NASA DC-8 CFM56 engines demonstrate particle emissions reductions from burning alternative fuels



Anderson, B.E. et al., NASA/TM-2011-217059, 2011
Beyersdorf A.J. et al., *Atmos. Chem. Phys.*, 2014
Moore, R.H. et al., *Energy & Fuels*, 2015



However, cruise conditions are very different from conditions on the ground, which necessitates in-flight testing



- Flight test series conducted at Edward AFB complex
- Falcons are slow, but can sample exhaust up close
- Two fuels: Jet A and 50:50 Jet A and Biofuel Blend
- Corresponding ground test to link to past studies



- Flight test series conducted in German air space
- DC-8 is fast, but was required to sample > 5 km in trail
- Three fuels: Jet A and 2 blends of varying composition
- Corresponding ground test
- Also sampled commercial aircraft flights of opportunity in the national air space targeting advanced engines









Finding: Jet Biofuels Reduce Soot Particle Emissions by 50-60%!



LETTER

Biofuel blending reduces particle emissions from aircraft engines at cruise conditions

Richard H. Moore¹, Kenneth L. Thornhill^{1,2}, Bernadett Weinzierl^{1,4}, Daniel Sauer^{3,5}, Eugenio D'Accolli^{3,5}, Jin Kim¹, Michael Lichtenstern¹, Monika Scheibel⁴, Brian Beaton¹, Andreas J. Beyerndorf⁴, John Barrick^{3,2}, Dan Bulzan⁷, Chelsea A. Cori⁸, Ewan Crosbie^{3,9}, Tina Jurkat¹, Robert Martin¹, Dean Riddick¹, Michael Shook^{3,2}, Gregory Slover¹, Christiane Voigt¹⁰, Robert White¹, Edward Winstead^{1,2}, Richard Yasky¹, Luke D. Ziemba¹, Anthony Brown¹¹, Hans Schlager¹ & Bruce E. Anderson¹

Aviation-related aerosol emissions contribute to the formation of contrail cirrus clouds that can alter upper tropospheric radiation and water budgets, and therefore climate¹. The magnitude of aircraft-related aerosol-cloud interactions and the ways in which these interactions might change in the future remain uncertain¹. Modelling studies of the present and future effects of aviation on climate require detailed information about the number of aerosol particles emitted per kilogram of fuel burned and the microphysical properties of those aerosols that are relevant for cloud formation¹. However, previous observational data at cruise altitudes are sparse for engines burning conventional fuels^{2,3}, and no data have previously been reported for biofuel use in-flight. Here we report observations from research aircraft that sampled the exhaust of engines onboard a NASA DC-8 aircraft as they burned conventional Jet A fuel and a 50:50 (by volume) blend of Jet A fuel and a biofuel derived from Camelina oil. We show that, compared to using conventional fuels, biofuel blending reduces particle number and mass emissions immediately behind the aircraft by 50 to 70 per cent. Our observations quantify the impact of biofuel blending on aerosol emissions at cruise conditions and provide key microphysical parameters, which will be useful to assess the potential of biofuel use in aviation as a viable strategy to mitigate climate change.

The global aviation sector contributes approximately 5% of the current anthropogenic radiative forcing, owing to direct emissions of fossil fuel CO₂ (26 mW m⁻²) and the formation and evolution of contrails and contrail-induced cirrus clouds (50 mW m⁻²)^{3,5}. Of these effects, the largest uncertainties are associated with aviation-induced cloudiness, both directly from contrail-induced cirrus clouds and indirectly from the contribution of black carbon, organic and sulfate aerosols that may act as cloud condensation nuclei and ice nuclei^{3,4,6,7}. With emissions of CO₂ from fuel expected to more than double by 2050, aviation-related contributions to radiative forcing may increase to 3–4 times the year 2000 levels⁸. Consequently, some governments are exploring ways to curb these emissions, and the International Air Transport Association (IATA) has targeted carbon-neutral growth by 2020 and a 50% reduction in carbon emissions by 2050 (ref. 9).

Sustainable biojet fuels are a promising route for mitigating greenhouse gas emissions. However, many challenges remain before aviation biofuels can be widely adopted, particularly with regard to cost and sustainability. Jet fuels are more highly refined than the biofuels used for surface transportation, with the latter perhaps presenting a "better biomass opportunity cost"¹⁰. However, unlike for aviation, there are many alternative energy solutions for surface transportation, other than liquid hydrocarbon-based fuels, that are realizable in the near future^{10,11}. Biojet fuels consist of a mixture of C₇–C₁₆ hydrocarbons that

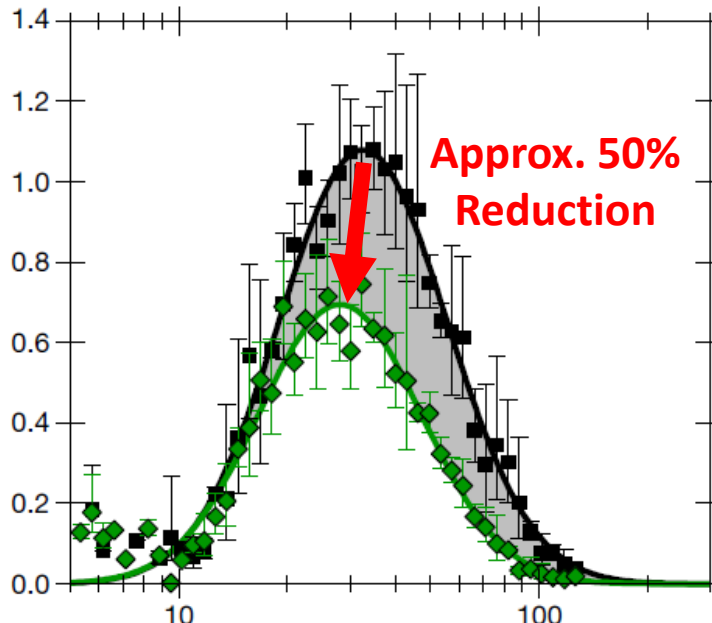
are typically formed via transesterification and subsequent hydroprocessing of plant and animal oils to produce a hydrotreated esters and fatty acids (HEFA) fuel that has many of the properties of petroleum-derived jet fuels^{12,13}. Promising plant-based feed stocks for future aviation biofuels include Jatropha, Camelina and algae¹⁴. Biojet fuels have potential as a future aviation fuel source that is not dependent on fossilized carbon and that contains near-zero levels of sulfur and aromatic species, which are commonly present in petroleum-based jet fuels at levels of several hundred parts per million by mass (p.p.m.), sulfur and around 20% aromatics by volume. Previous laboratory and ground test experiments using bio-based fuels or synthetic Fischer-Tropsch fuels produced from natural gas and coal feed stocks show that the absence of sulfur and aromatic species within the fuel substantially reduces the sulfate and black carbon particle emissions from aircraft engines^{15,16}. These results are important for reducing the impact of aviation on local air quality near airports and suggest that similar reductions are likely to be observed at high-altitude cruise conditions; however, the engine operating conditions on the ground (for example, temperature, pressure, fuel flow rates, fuel/air ratio and maximum thrust) are very different from those in flight.

Here we report airborne measurements of jet engine exhaust, sampled at cruise conditions, from engines burning both a blended biofuel and a conventional jet fuel. Research aircraft from NASA, the German Aerospace Center (DLR) and the National Research Council (NRC) Canada were equipped with state-of-the-art instrumentation and sampled the exhaust of the NASA DC-8 turbofan engines at atmospheric and engine conditions that are exclusively met in flight. The tests were conducted during 2013–2014 as part of the Alternative Fuel Effects on Contrails and Cruise Emissions Study (ACCESS) at NASA Armstrong Flight Research Center in Palmdale, California, USA.

The DC-8 source aircraft has four wing-mounted CFM56-2-C1 engines that can be fed fuel from any of four segregated fuel tanks within the wings. During the flight experiments, these tanks contained either a medium- or low-sulfur-content Jet A fuel, while a fuselage-mounted auxiliary tank contained an approximately 50:50 (by volume) blend of a low-sulfur-content Jet A fuel and a Camelina-based HEFA biojet fuel (see Methods).

The exhaust plumes from the left and right inboard DC-8 engines were sampled by research aircraft flying in a trailing formation at a distance of 30–150 m (plume age of about 0.15–0.75 s) behind the DC-8 (Fig. 1). This short distance assures that the plumes from specific engines did not mix. Three different fuels and three different engine thrust conditions were investigated, which bracket the range of realistic flight conditions on the DC-8 flight curve (Fig. 1d). Commercial aircraft typically fly at thrust conditions at or slightly above the "maximum range" point, at which the quotient of drag and Mach

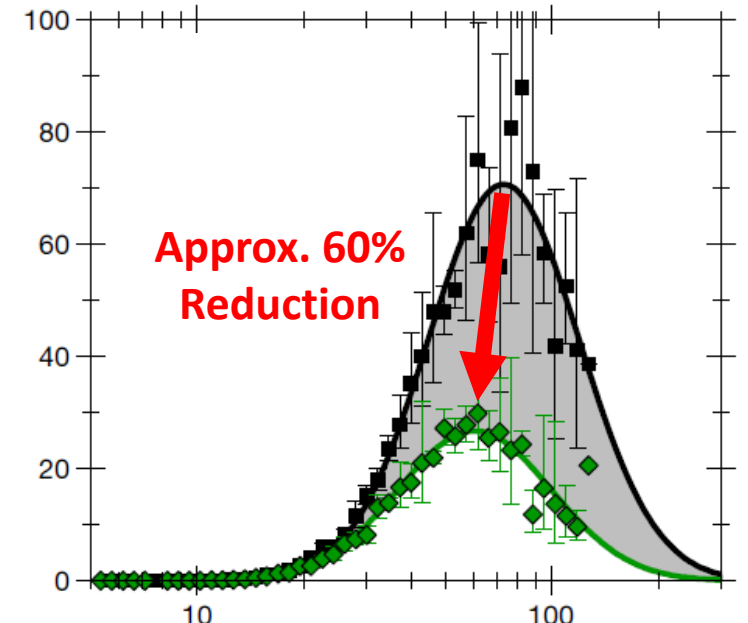
Number of non-volatile particles emitted per kilogram fuel burn (10¹⁵ kg-fuel⁻¹)



Dry Particle Diameter (nm)



Volume of non-volatile particles emitted per kilogram fuel burn (mm³ kg-fuel⁻¹)

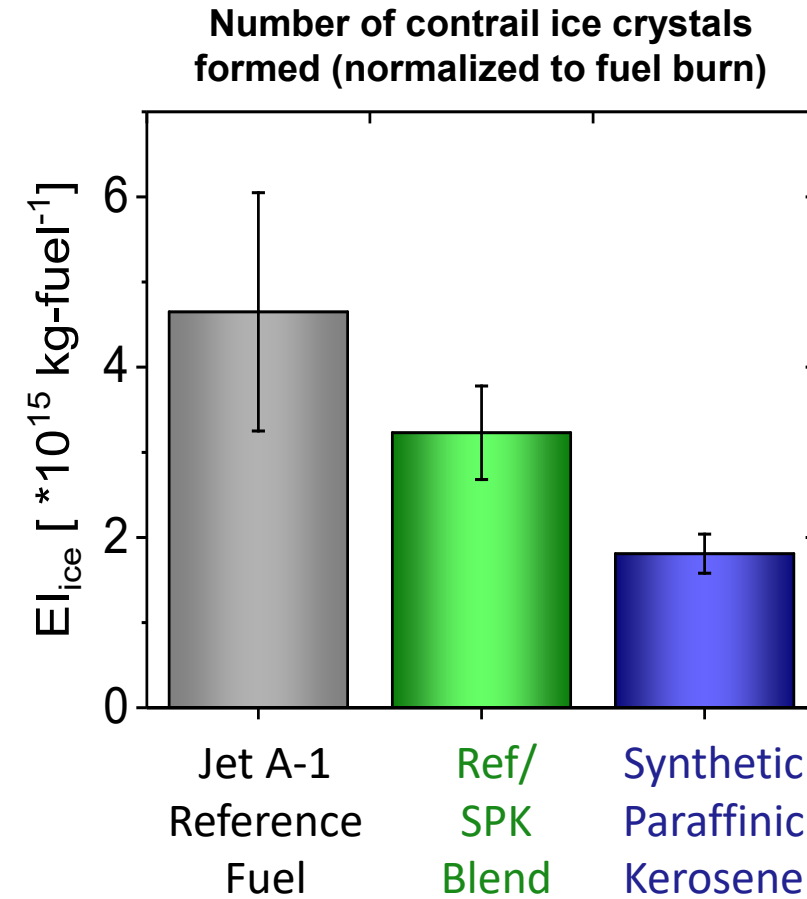
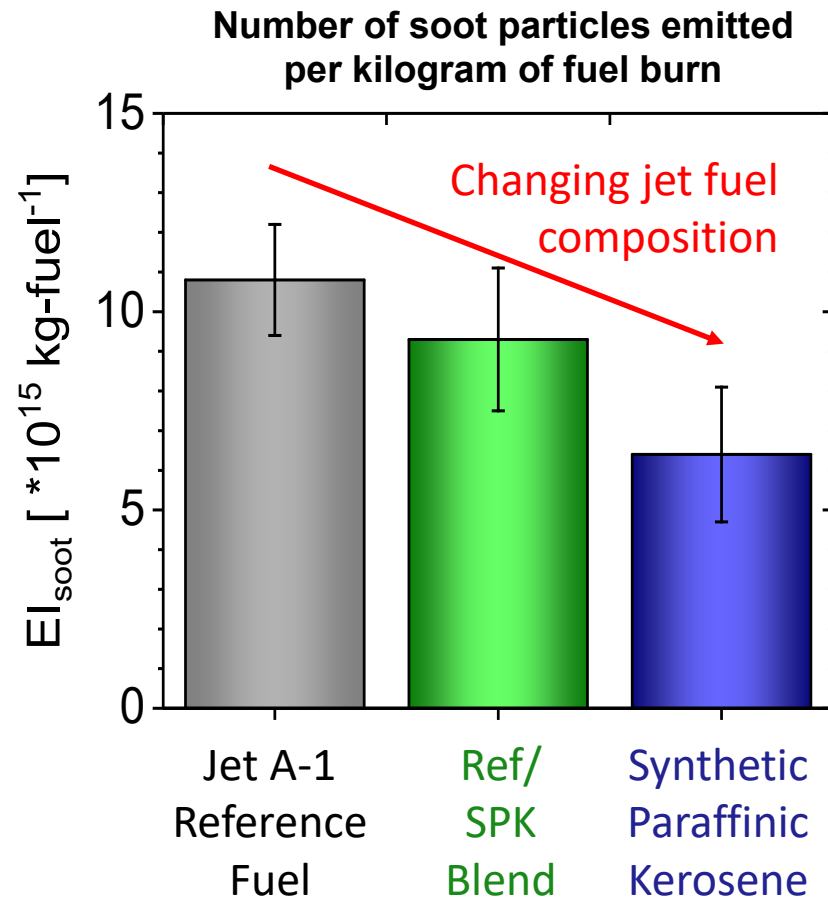


Dry Particle Diameter (nm)

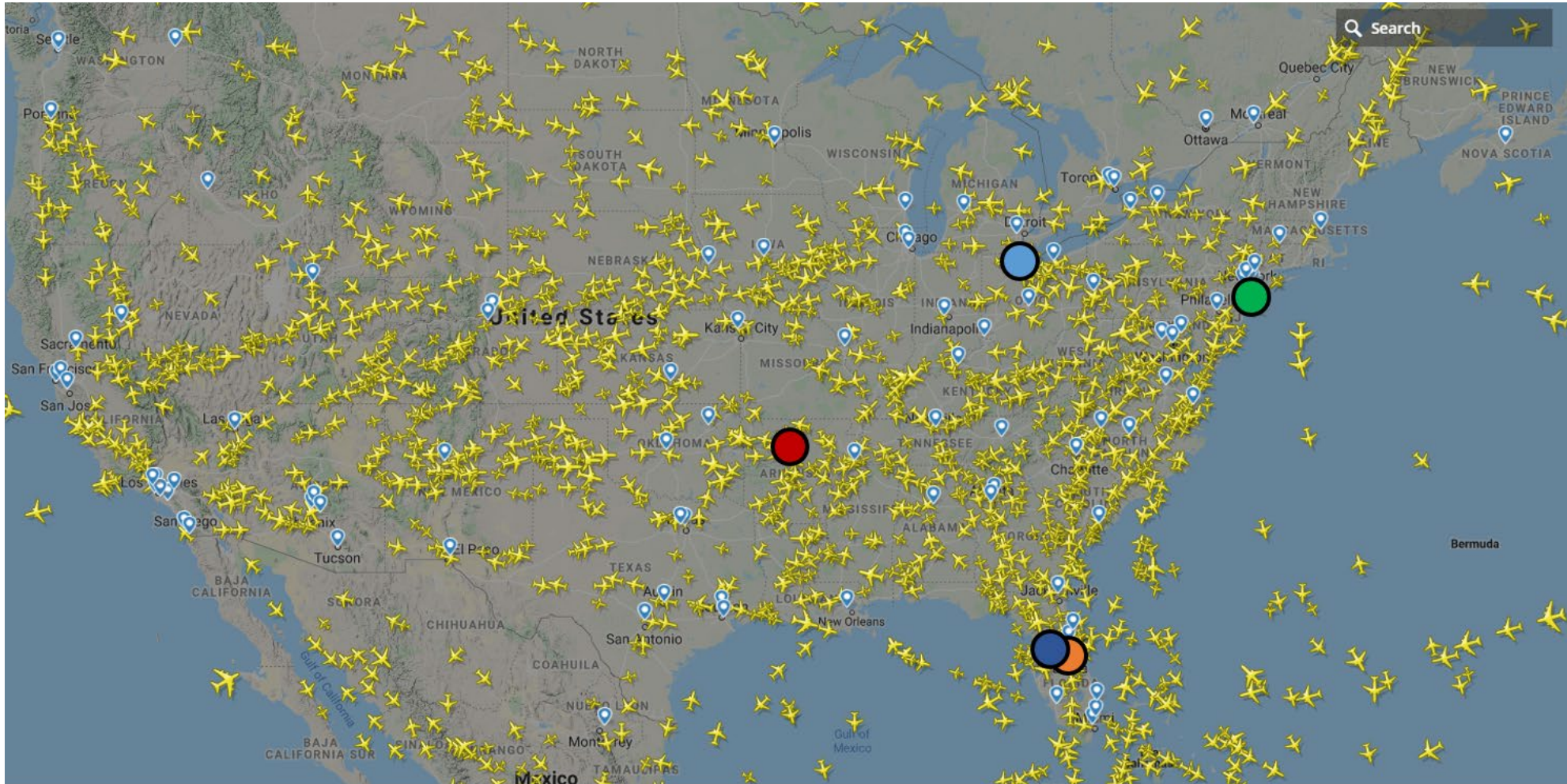




Finding: These Soot Particle Emissions Reductions Directly Translate Into Contrail Ice Crystal Number Reductions!



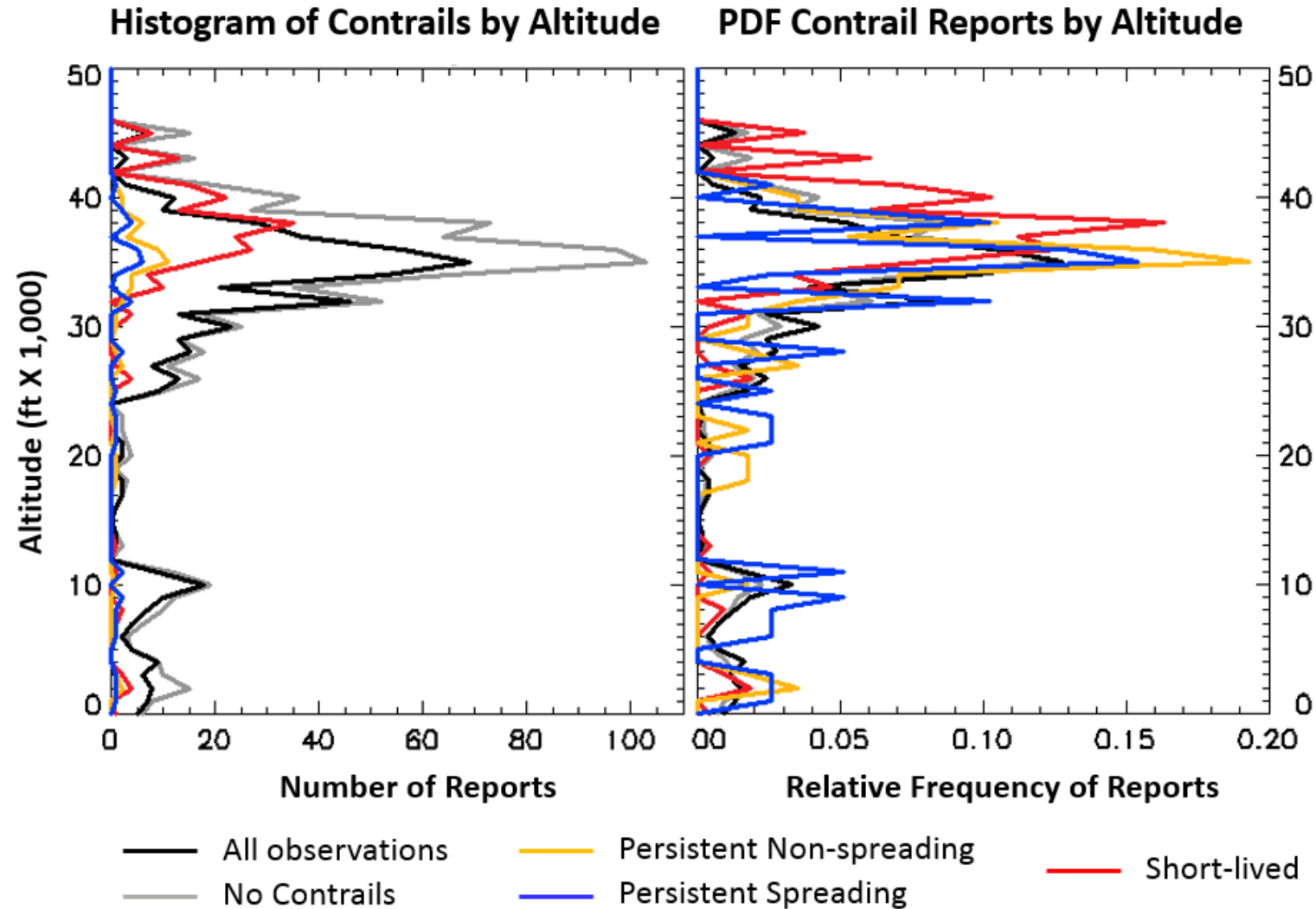
New Citizen Science Project Combining GLOBE Observer With FlightRadar24 Aircraft Augmented Reality



- Alpena Elementary/Middle School, Alpena AR
- Montverde Academy, Montverde, FL
- Treadway Elementary, Leesburg, FL
- Lexington School for the Deaf, East Elmhurst, NY
- University of Toledo, Toledo, OH

Contact Marilé Colón Robles – Marile.ColonRobles@nasa.gov

Statistics Provided By The Students Enable NASA Researchers To Test Their Contrail Prediction Models





B61005 jetBlue

EWR ✈️ **FLL**
New York Fort Lauderd...

4 mi away

WN4845 Southwest

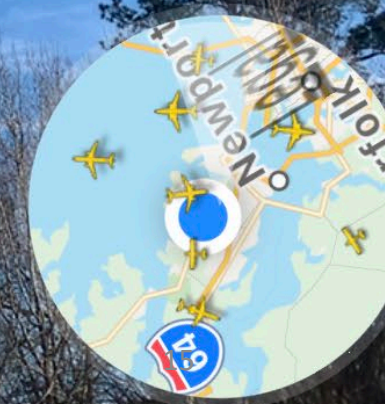
MCO ✈️ **PHL**
Orlando Philadelphia

13 mi away

N2593Z

CRE ✈️ **N/A**
North Myrtle...

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Overview Details

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