Verändern alternative Treibstoffe die Emissionen des Luftverkehrs und seine Klimawirkung?

Christiane Voigt
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and University Mainz

AK Energie 9

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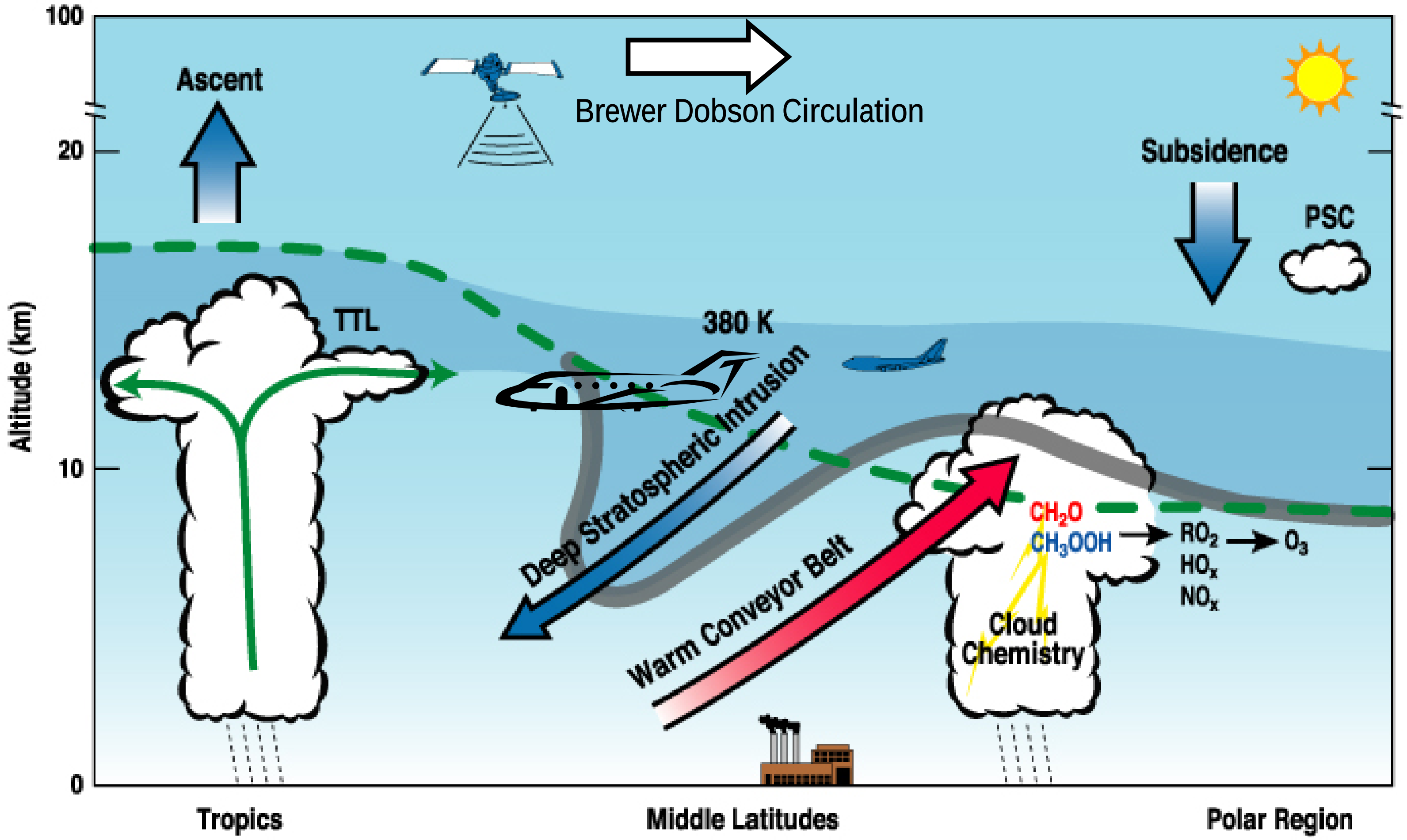
Aviation and the global atmosphere

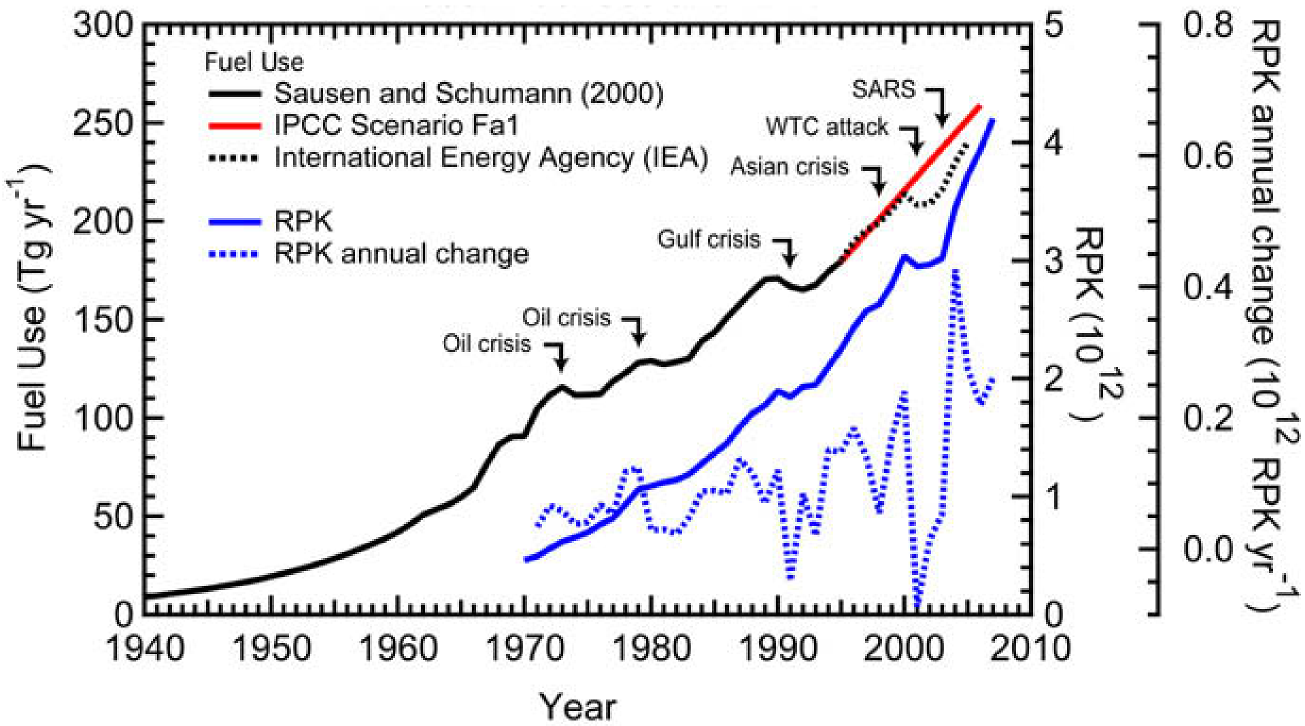


Pan et al., SPARC, 2006

Aviation emissions

Spezies	Emissions-index, g/kg (Bereich)	Emissions-rate (2004) in Tg/Jahr	Vergleichbare Emissions-rate, Tg/Jahr	Vergleichbare Emissions-quelle
Kerosin		200	3600 280 1320	Gesamte Erdölproduktion Globaler Schiffsverkehr Globaler Straßenverkehr
CO_2	**3160**	**630**	**26500** 800	**Gesamte anthropogene CO_2 Emissionen** Anthropogene CO_2 Emissionen in Deutschland
H_2O	1230	246	45 525000	Methan Oxidation in der Stratosphäre Verdampfung von H_2O an der Erdoberfläche
NO_x	13	2.6	0.7-2, 17±10 170±20	Stratosphärische Quellen Blitzquelle Gesamte atmosphärische anthropogene Quelle
Ruß	0.025 (0.01-0.05)	0.004 (AERO2K)	12	Verbrennung von fossilen Treibstoffen und Biomasse
SO_2	0.8 (0.6-1.0)	0.16	130 20-100 5.4, 8.0	Gesamte Quelle aus Verbrennung fossiler Treibstoffe Natürliche Quellen Nicht-eruptive, eruptive Vulkane
CO	3 (2-4)	0.507	2800	Gesamte anthropogene Quellen
HC	0.4 (0.1-1.0)	0.063	90	Gesamte anthropogene Quellen

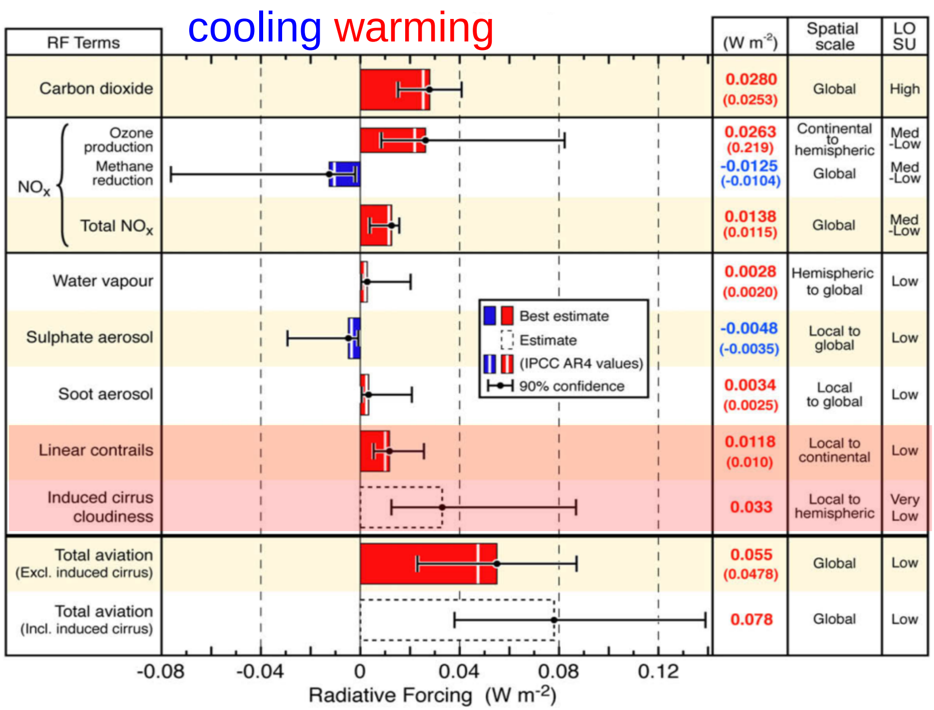
Growth rates in aviation



Lee et al., Atmos. Env., 2009

Climate impact from aviation

Aviation Radiative Forcing Components in 2005



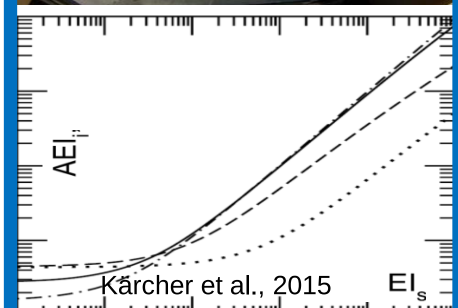
Lee et al., Atmos. Env., 2009

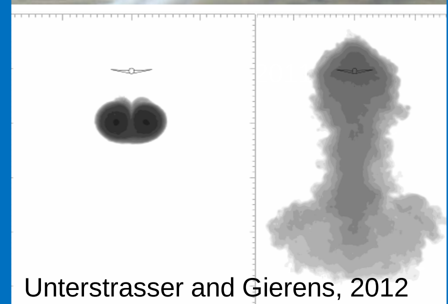
➢ Potentially large contribution from induced cirrus cloudiness.

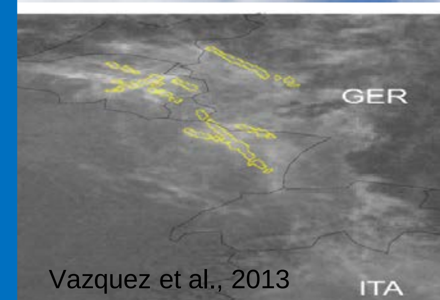
Life Cycle of Contail Cirrus

Climate Impact

Nucleation Growth Dispersion Sublimation

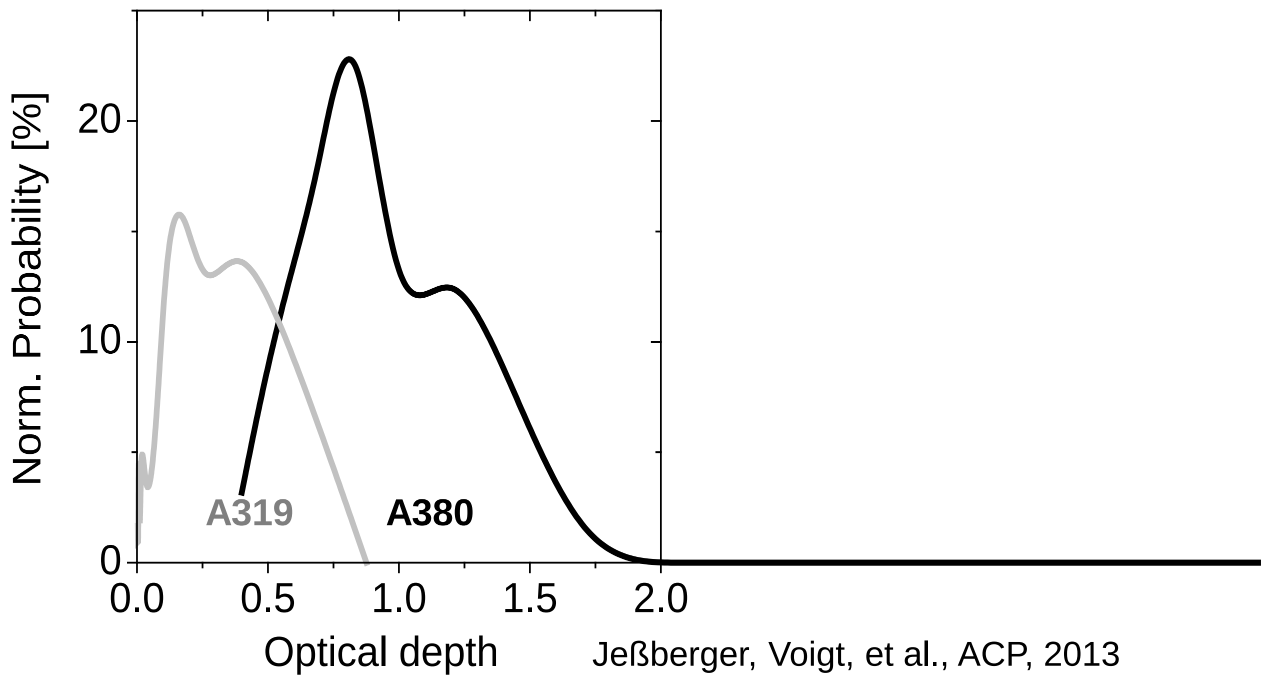






Lufthansa

Is there an effect of the aircraft type on contrail properties?



Jeßberger, Voigt, et al., ACP, 2013

- A380 emits more H_2O and soot per flight-km than A319 -> Larger contrail extinction
- Deeper descent of the vortices, larger vertical extension -> Larger contrail optical depth
- Averaged per passenger-km, a larger aircraft has a smaller climate impact

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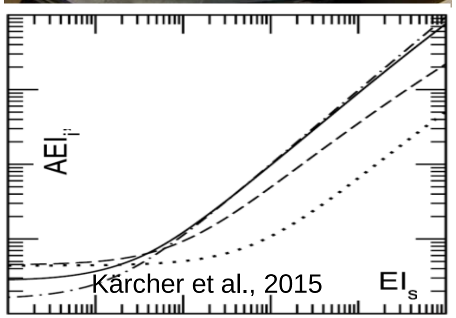
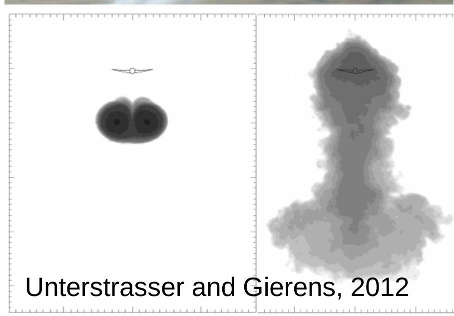
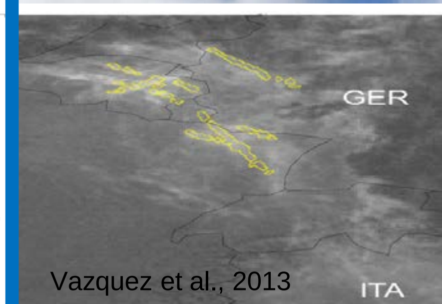
Life Cycle of Contail Cirrus

Climate Impact

Nucleation **Growth** **Dispersion** **Sublimation**







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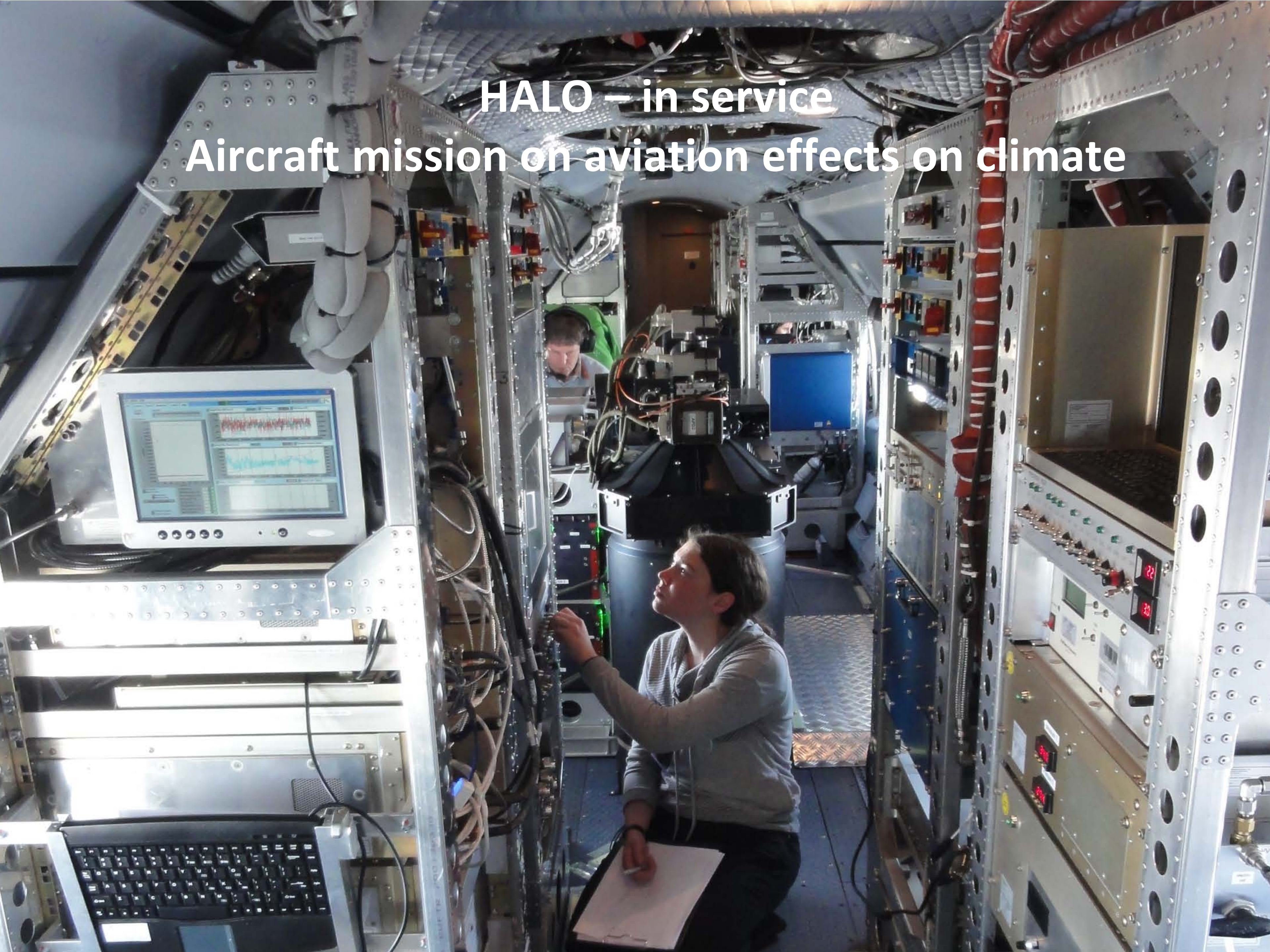
HALO – in service
Aircraft mission on aviation effects on climate

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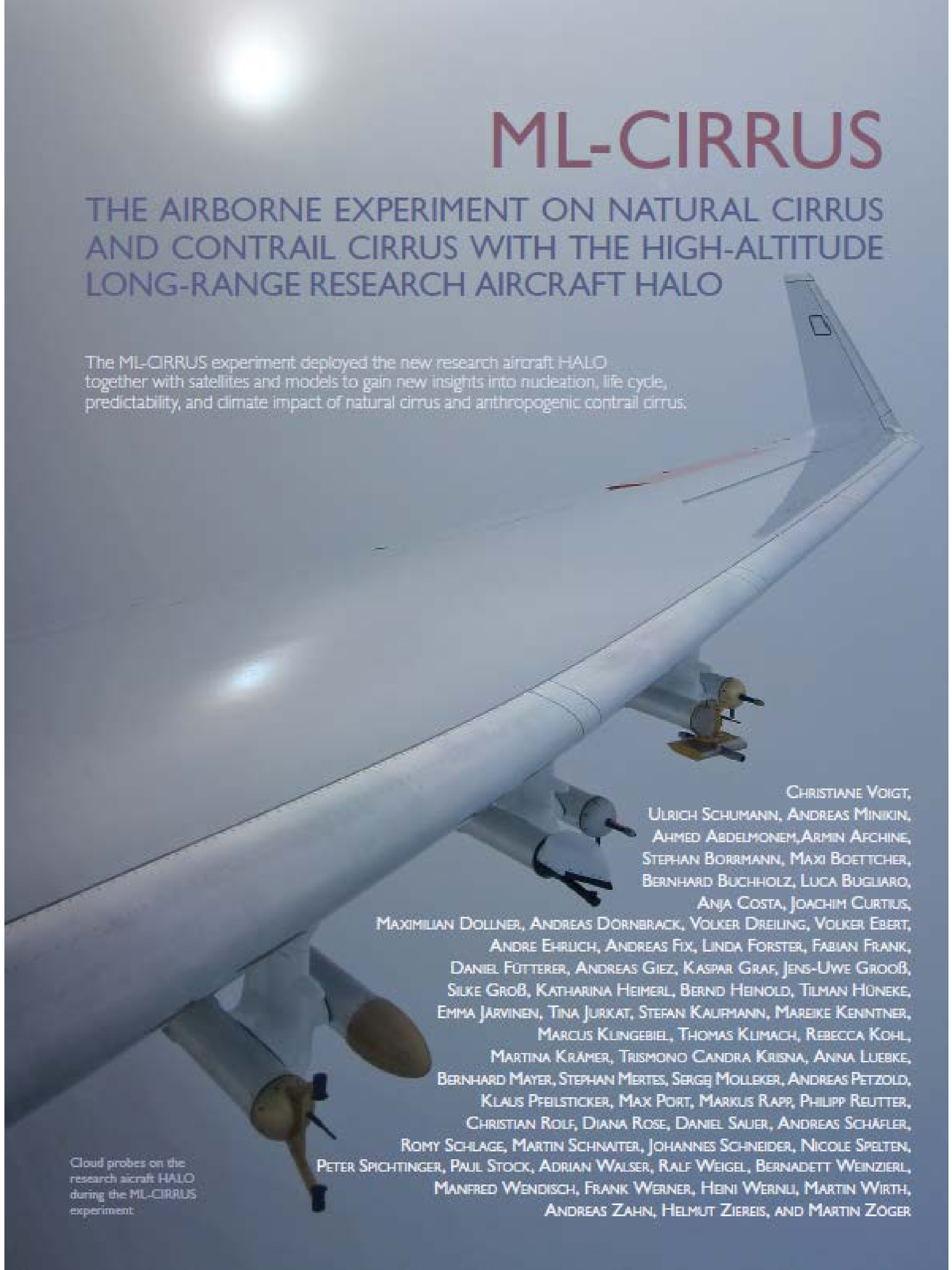

ML-CIRRUS

THE AIRBORNE EXPERIMENT ON NATURAL CIRRUS AND CONTRAIL CIRRUS WITH THE HIGH-ALTITUDE LONG-RANGE RESEARCH AIRCRAFT HALO

The ML-CIRRUS experiment deployed the new research aircraft HALO together with satellites and models to gain new insights into nucleation, life cycle, predictability, and climate impact of natural cirrus and anthropogenic contrail cirrus.

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Ulrich Schumann, Andreas Minikin,
Ahmed Abdelmonem, Armin Afchine,
Stephan Borrmann, Maxi Boettcher,
Bernhard Buchholz, Luca Bugliaro,
Anja Costa, Joachim Curtius,
Maximilian Dollner, Andreas Dörnbrack, Volker Dreiling, Volker Ebert,
Andre Ehrlich, Andreas Fix, Linda Forster, Fabian Frank,
Daniel Fütterer, Andreas Giez, Kaspar Graf, Jens-Uwe Grooß,
Silke Groß, Katharina Heimerl, Bernd Heinold, Tilman Hüneke,
Emma Järvinen, Tina Jurkat, Stefan Kaufmann, Mareike Kenntner,
Marcus Klingebiel, Thomas Klimach, Rebecca Kohl,
Martina Krämer, Trismono Candra Krisna, Anna Luebke,
Bernhard Mayer, Stephan Mertes, Sergej Molleker, Andreas Petzold,
Klaus Pfeilsticker, Max Port, Markus Rapp, Philipp Reutter,
Christian Rolf, Diana Rose, Daniel Sauer, Andreas Schäfler,
Romy Schlage, Martin Schnaiter, Johannes Schneider, Nicole Spelten,
Peter Spichtinger, Paul Stock, Adrian Walser, Ralf Weigel, Bernadett Weinzierl,
Manfred Wendisch, Frank Werner, Heini Wernli, Martin Wirth,
Andreas Zahn, Helmut Ziereis, and Martin Zöger

Cloud probes on the research aircraft HALO during the ML-CIRRUS experiment

Voigt et al., BAMS, 2017

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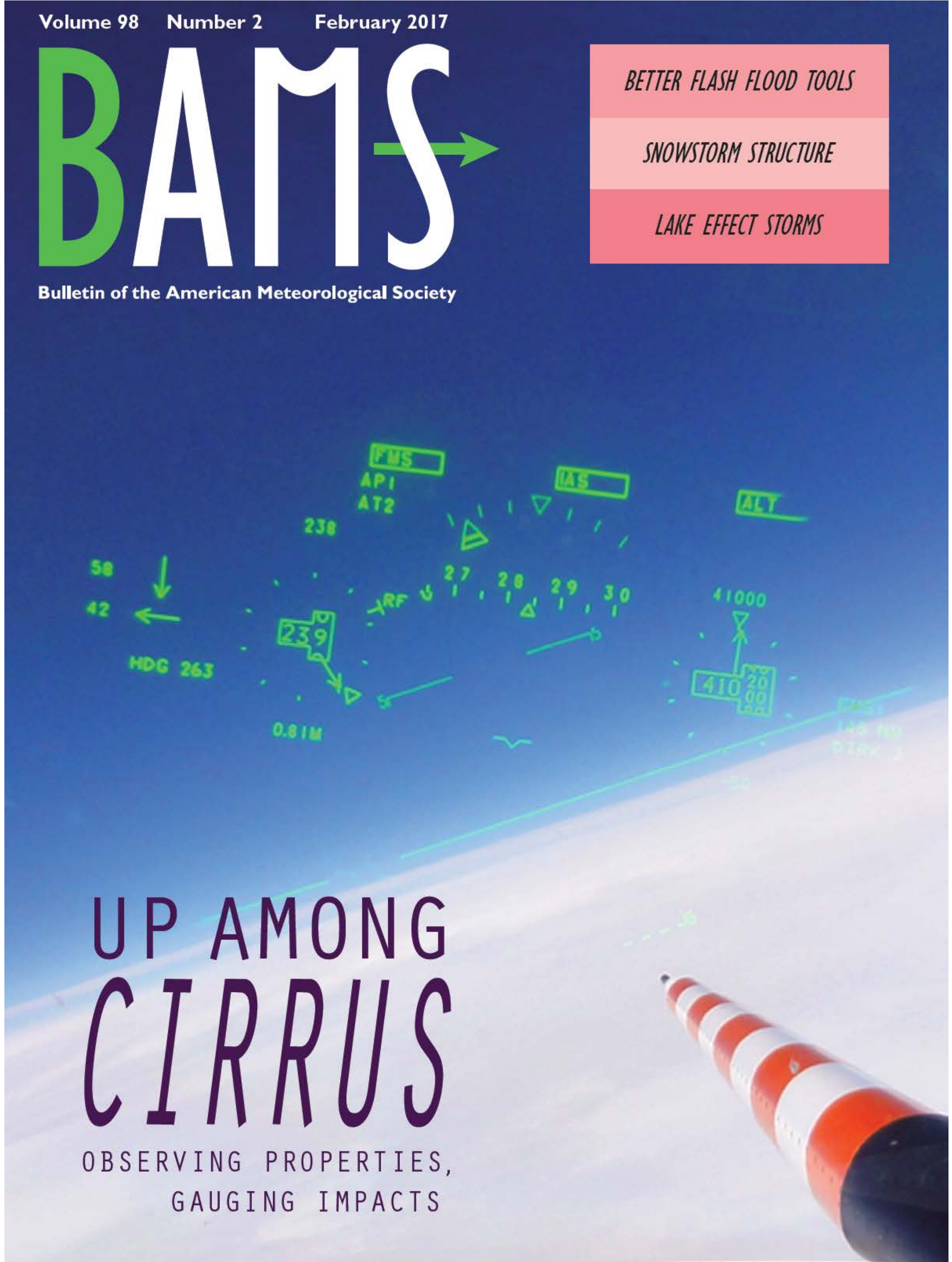
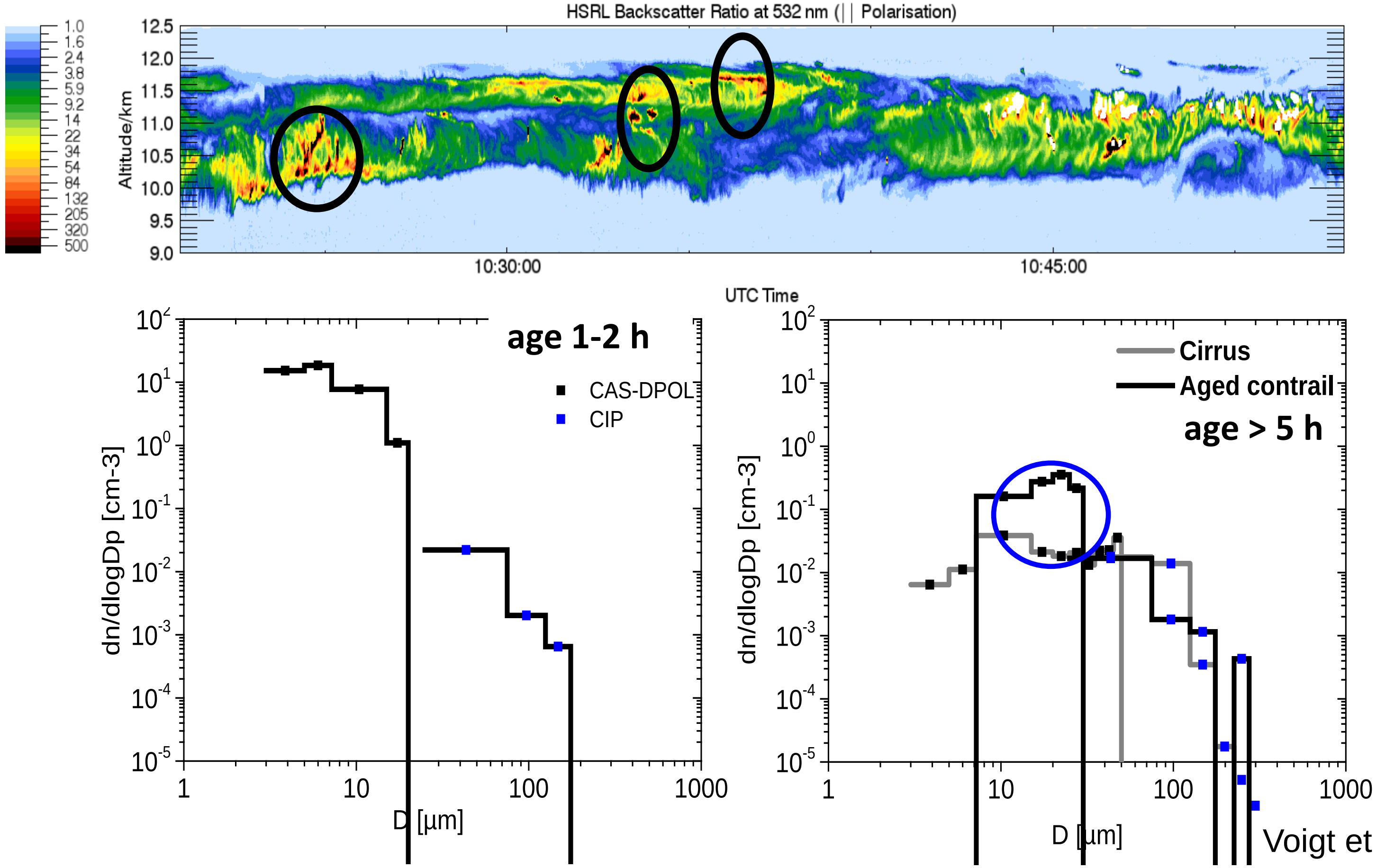


Voigt et al., BAMS, 2017

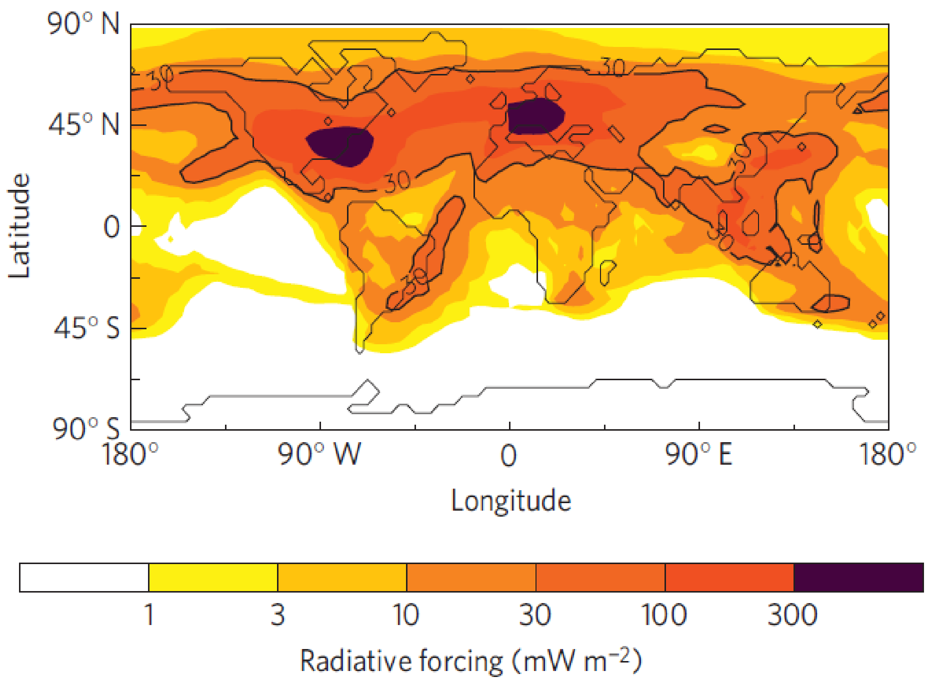
Particle size distribution in contrail cirrus



Voigt et al., BAMS, 2017

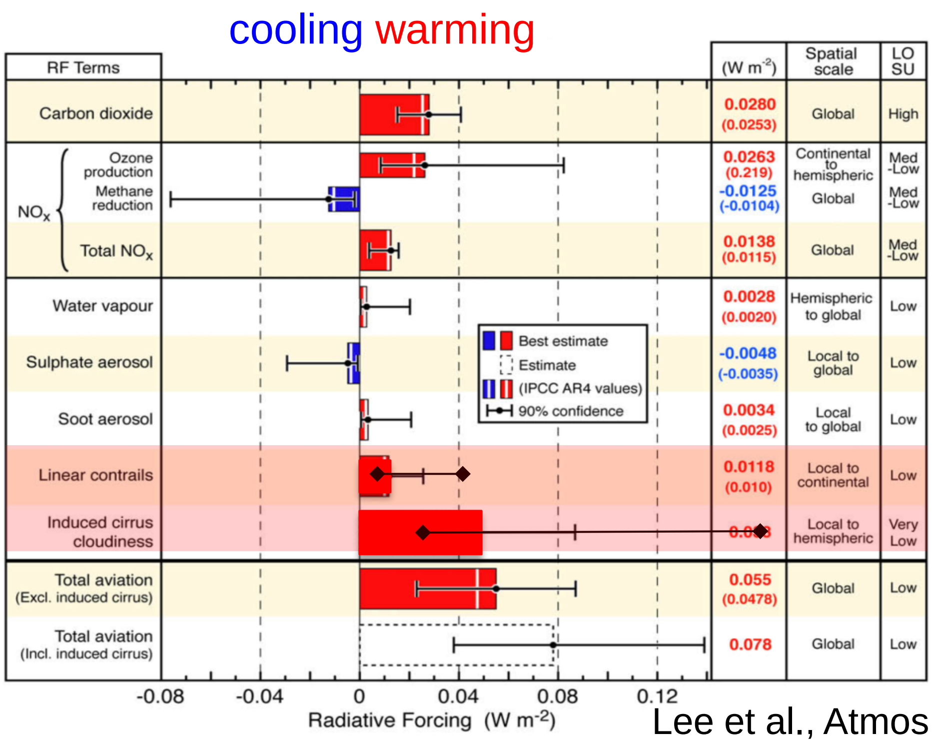
- Even after 5 h contail cirrus still differ from natural cirrus
- Effects on climate ? Higher n -> higher extinction & τ

Radiative forcing from contrail cirrus



Burkhardt and Kärcher, Nature Clim. Change, 2011

Aviation Radiative Forcing Components in 2005/2011



Lee et al., Atmos. Env., 2009

Voigt et al., GRL, 2011
Burkhardt & Kärcher, Nature Clim Change, 2011
Schumann & Graf, JGR, 2012

IPCC 2013: “Based on these studies we assess the combined contrail and contrail-induced cirrus effective radiative forcing for the year 2011 to be +0.05 (+0.02 to +0.15) W m^{-2}.”

- ➢ Contrail cirrus constitute the largest component of aviation climate impact.
- ➢ Contrail lifetime of few hours allows fast mitigation of their climate effects.

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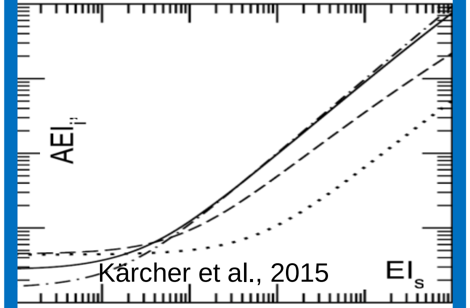
Life Cycle of Contail Cirrus

Climate Impact

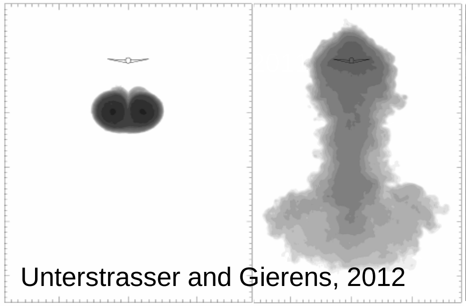
Nucleation **Growth** **Dispersion** **Sublimation**

Moore et al., 2017

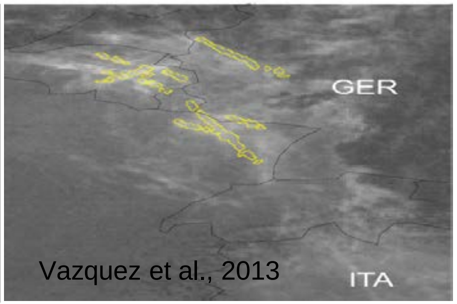


Kärcher et al., 2015

Voigt et al., 2011


Unterstrasser and Gierens, 2012

Voigt et al., 2017



Vazquez et al., 2013

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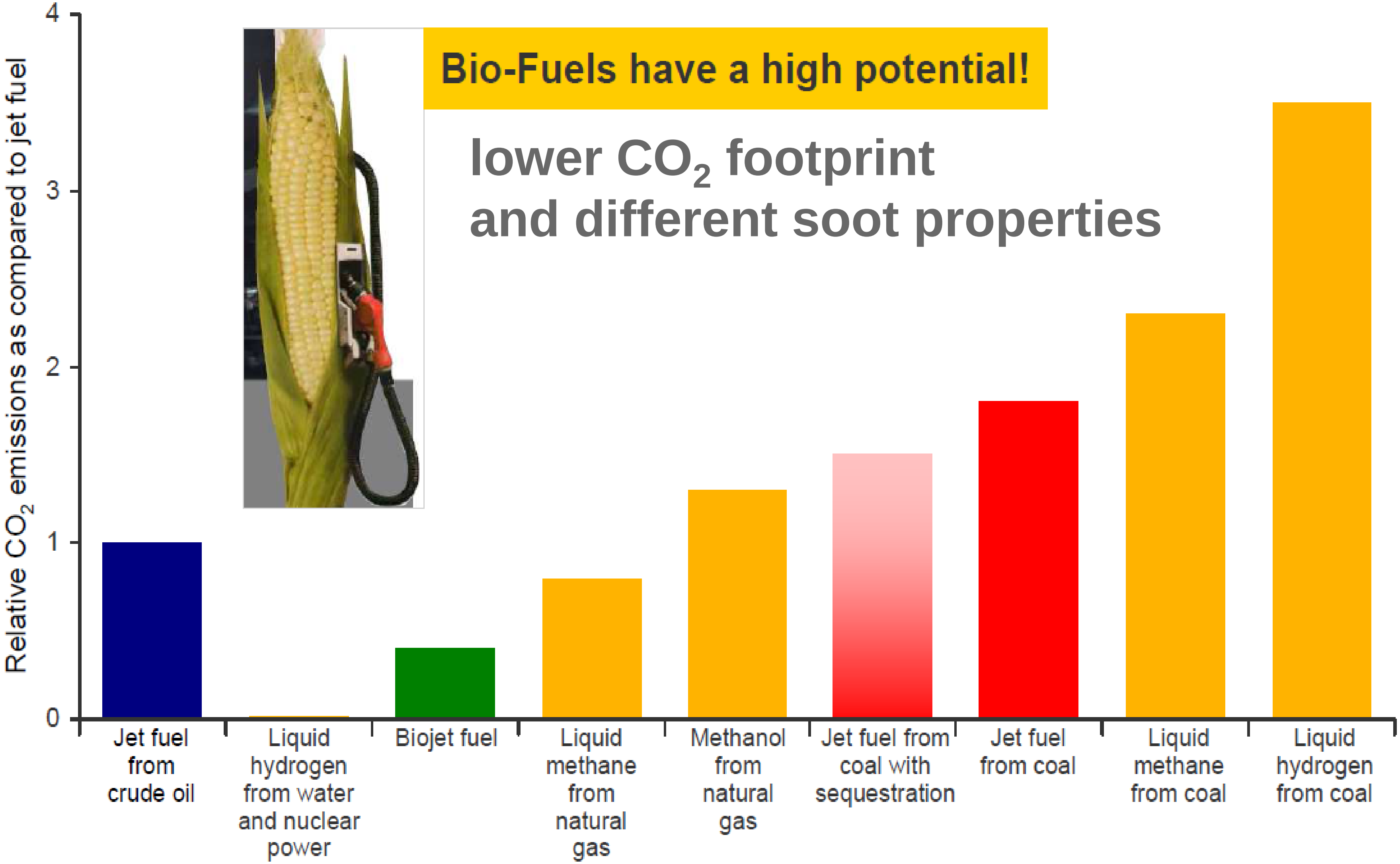
CO_2 footprint from different fuels

Bio-Fuels have a high potential!

lower CO_2 footprint
and different soot properties



ACCESS
Alternative-Fuel Effects on Contrails & Cruise Emissions

Biofuel: 50% HEFA Hydroprocessed Ester and Fatty Acids from Camelina plant

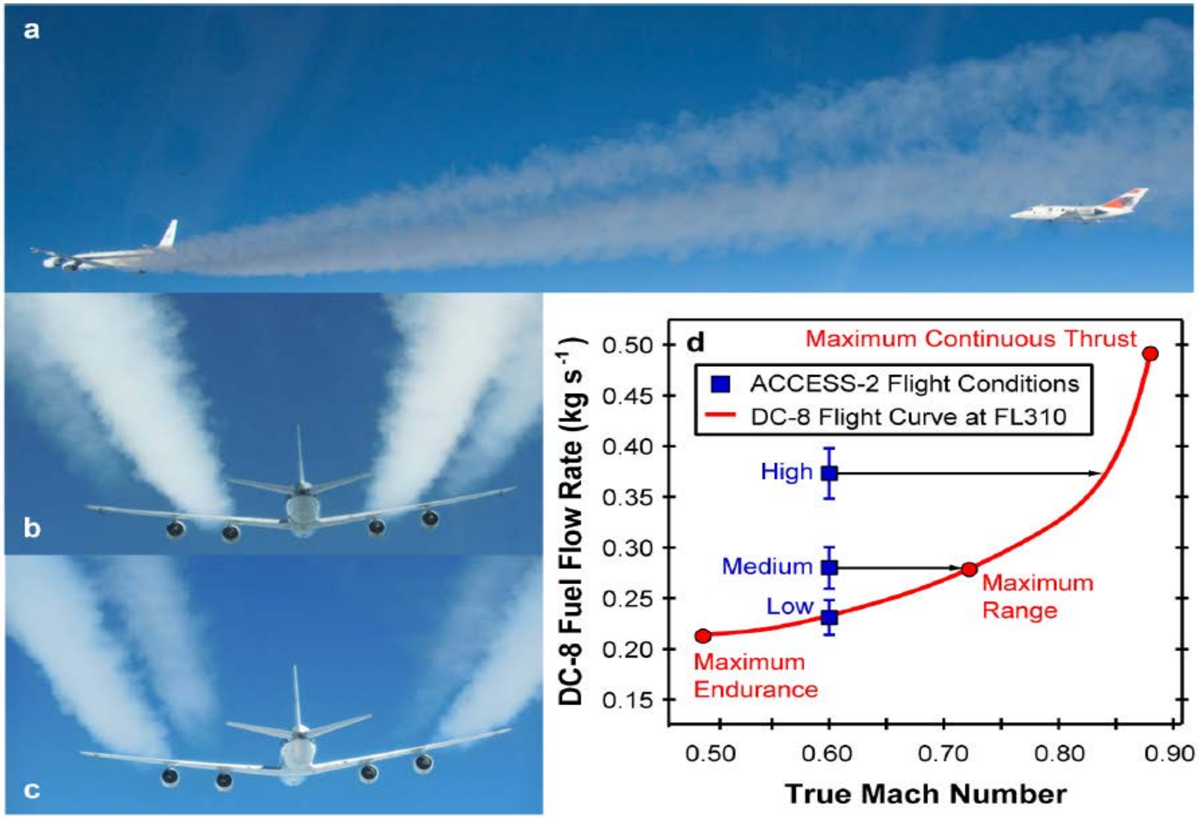
ACCESS
Alternative-Fuel Effects on Contrails & Cruise Emissions

Biofuel: 50% HEFA Hydroprocessed Ester and Fatty Acids from Camelina plant

Anderson, NASA

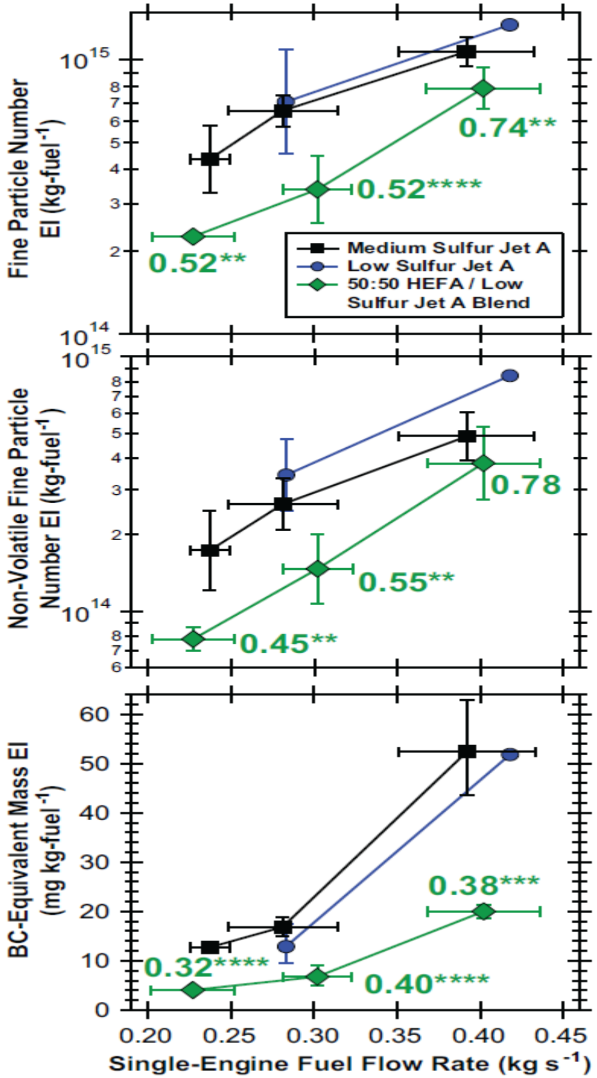
ACCESS
Alternative-Fuel Effects on Contrails & Cruise Emissions

CFM65 engine



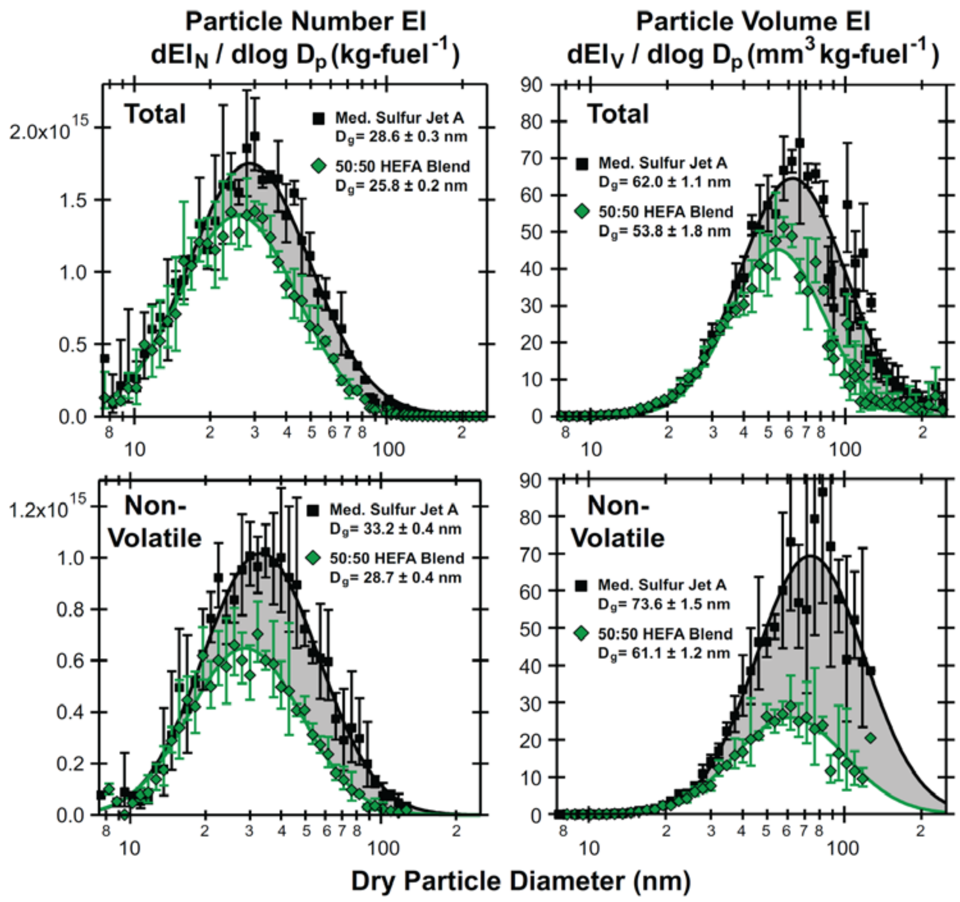
Moore, Thornhill, Voigt et al., Nature 2017

Reduction in particle number densities by 50% HEFA blend



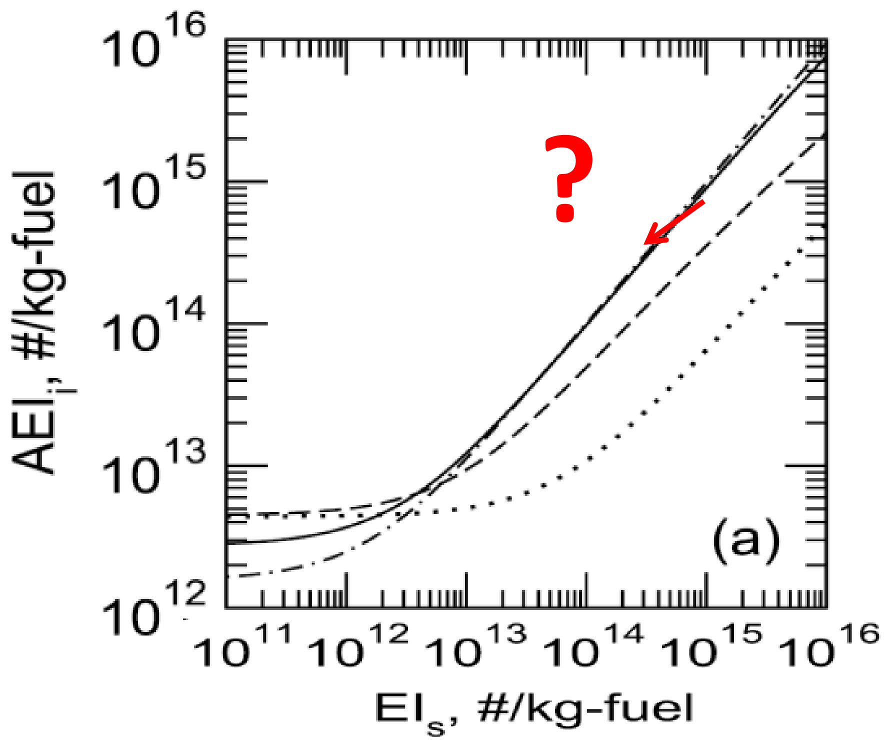
Moore, Thornhill, Voigt et al., Nature 2017

Reduction in particle number and size by 50% HEFA blend



Moore, Thornhill, Voigt et al., Nature 2017

Emission index of soot – Emission index of contrail ice



Kärcher et al., 2015

➢ Is there a reduction in AEI_{ice} for reduced soot EI_s when using bio fuels?

ECLIF Emission and Climate Impact of alternative Fuels
Synthetic Fuels with 8 to 19 % aromatic content

- Campaign with Falcon chasing A320 and engine tests (V2575)
- 5 flights in contrail conditions
- Near and far field contrail probing

Fotos Voigt, Woudsma @ DLR

- Biofueld and synthetic fuels with low aromatic content have the potential to reduce soot emissions and contrail lifetime – smaller climate impact

Thank you!