



UNIVERSITÄT  
LEIPZIG

# Climate impact of aircraft-induced cirrus assessed from satellite observations before and during COVID-19

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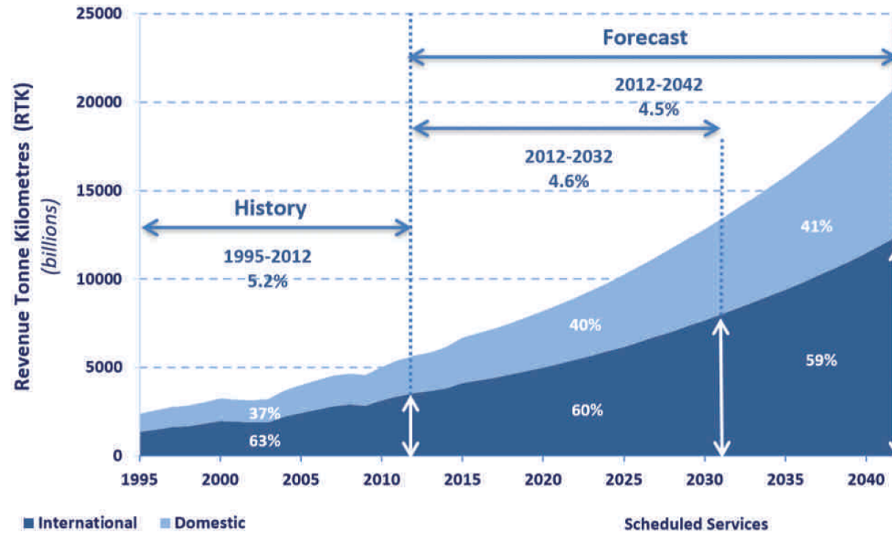


**ACACIA**



Horizon 2020  
European Union Funding  
for Research & Innovation

# Motivation

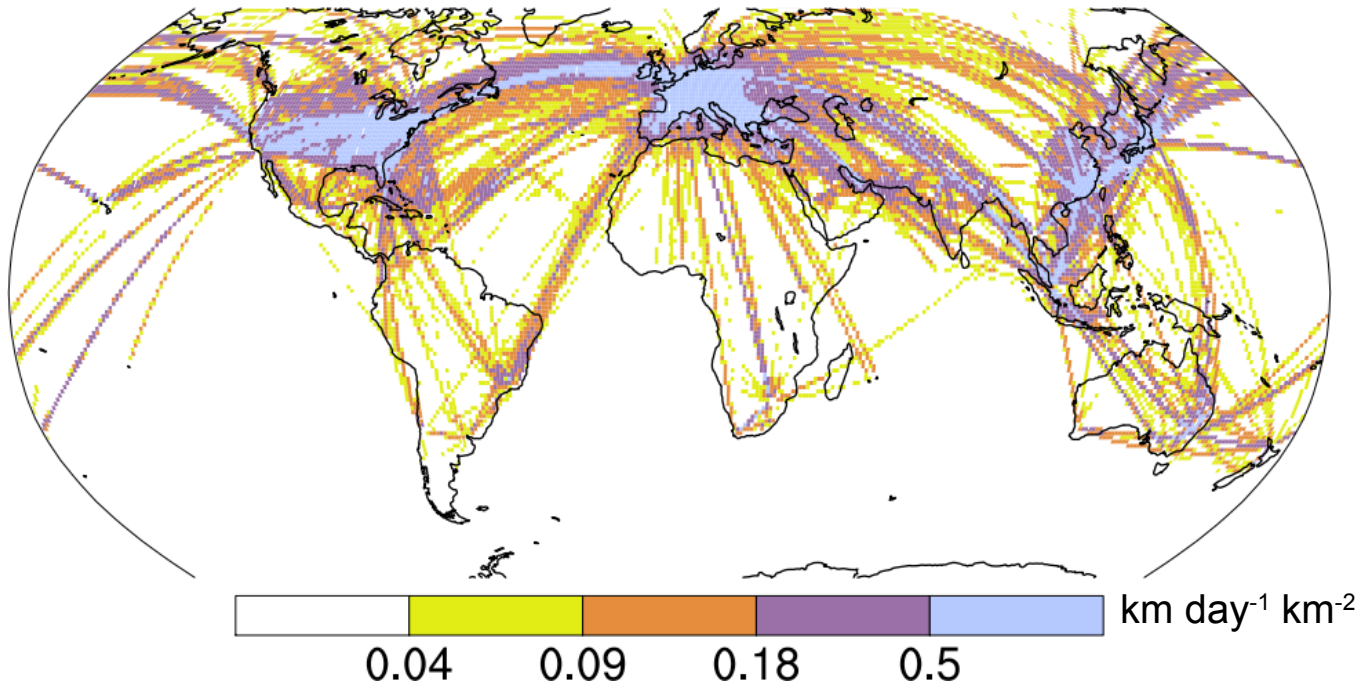


Aviation increases exponentially



Unclear magnitude of aviation effect on cirrus

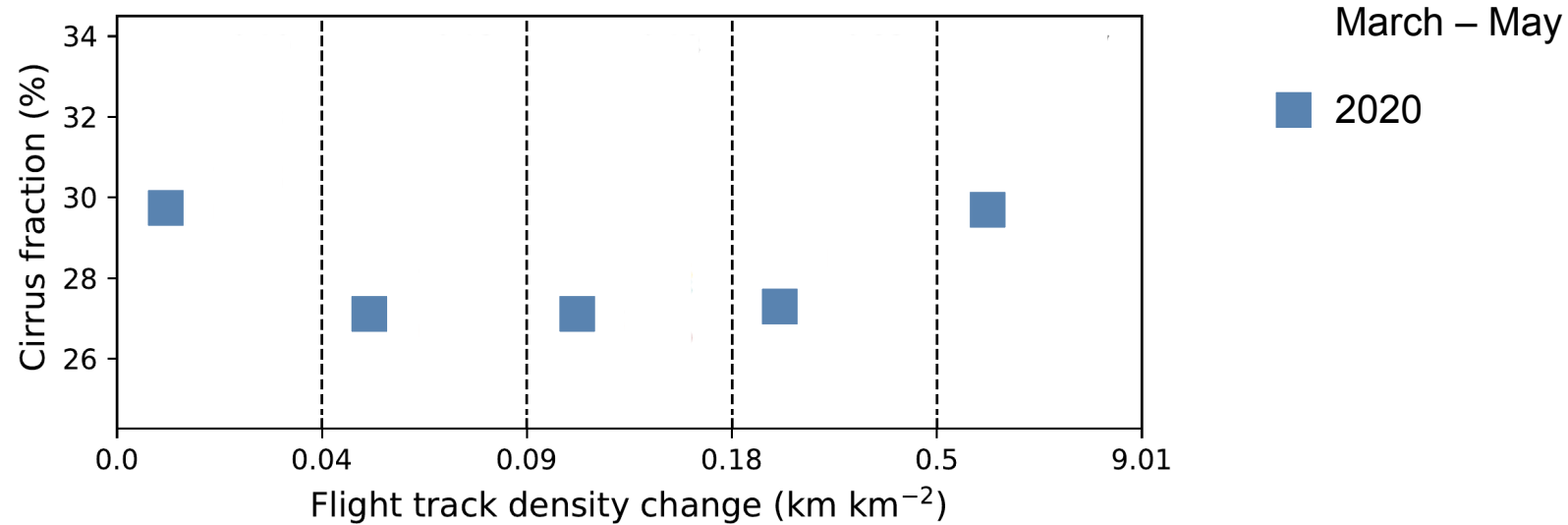
## Change in aviation



FlightRadar24 flight track density 2019 minus 2020

Colour bar selects five quintiles of area in Northern hemisphere mid-latitudes  
→ will be used for sampling in following plots

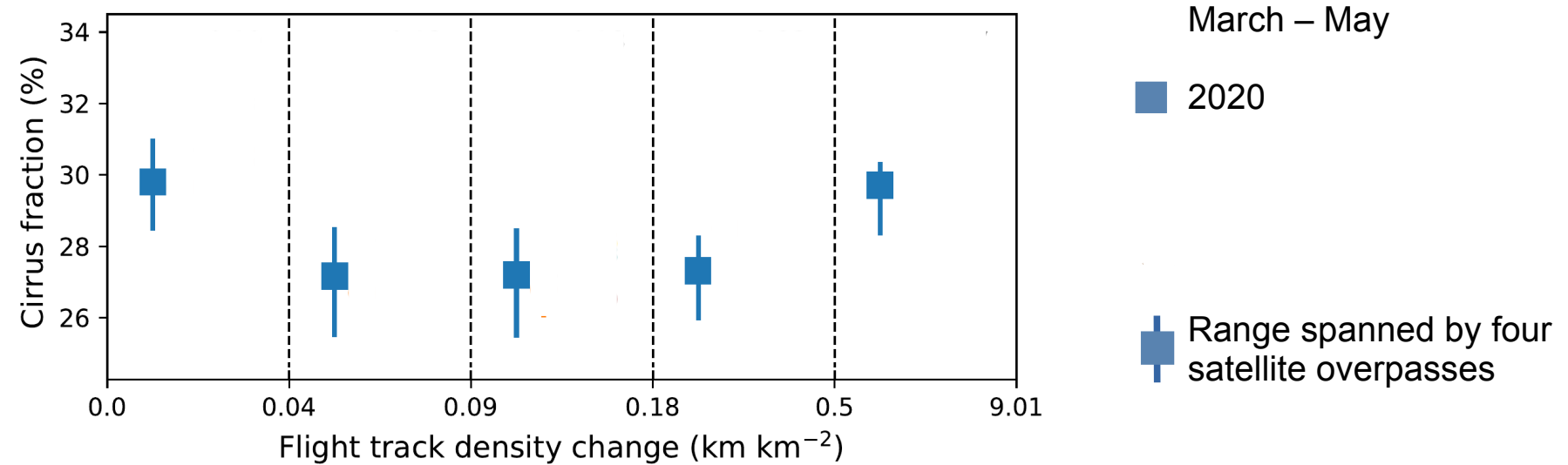
## Cirrus fraction & emissivity in regions with air traffic change; 2020 vs. past



### MODIS cirrus fraction

- from MOD08\_D3 and MYD08\_D3 (Terra / 10.30 h and MODIS Aqua / 1.30 h)
- joint histogram, cloud-top pressure < 320 hPa, emissivity < 0.95
- Northern hemisphere mid-latitudes, 27°N - 68°N
- Boreal spring, March – May
- grid-boxes that contain cirrus

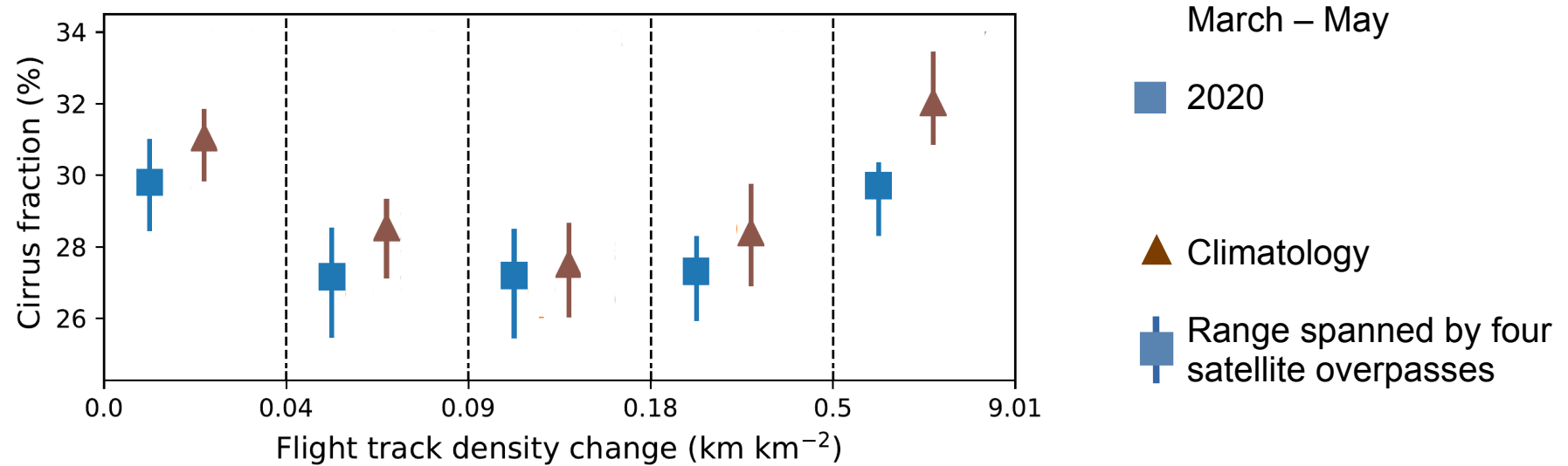
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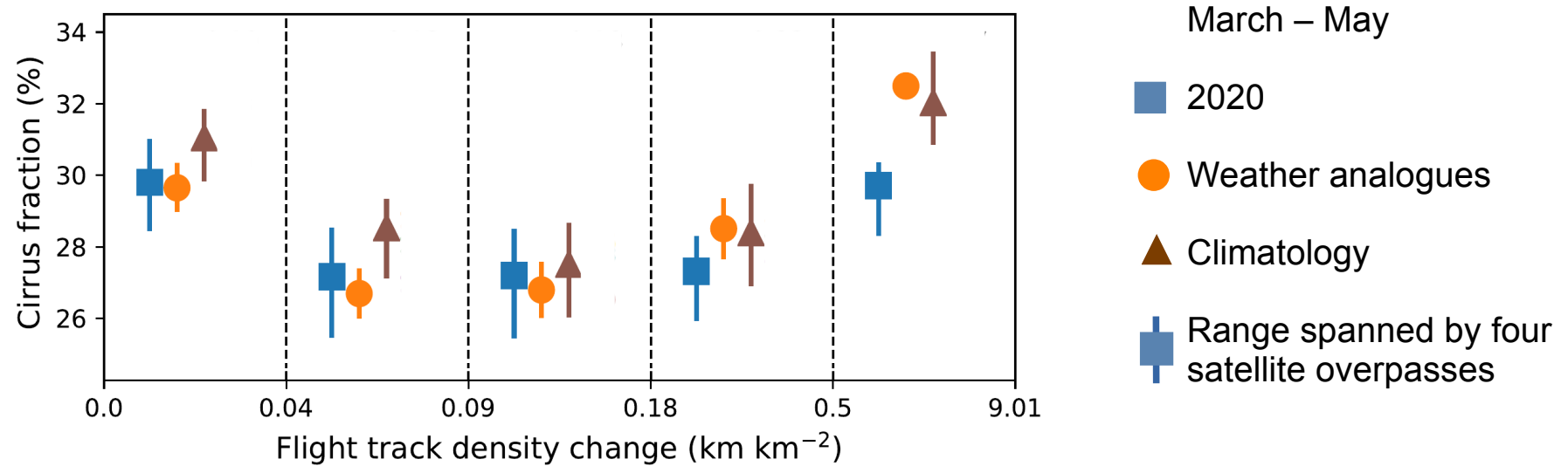
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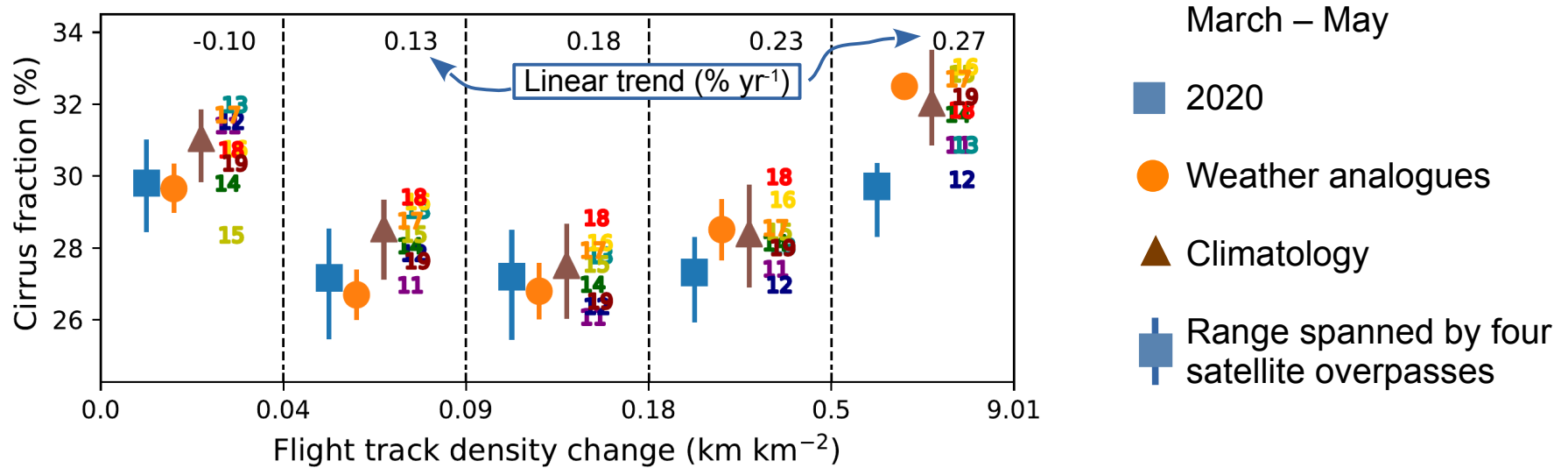
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### Circulation analogues

- pattern correlation of 500 hPa geopotential (NCEP reanalysis) within 5°x5° grid-boxes
- select up to 50 cases ( $r^2 > 0.5$ ) from 2011 – 2019 reference period

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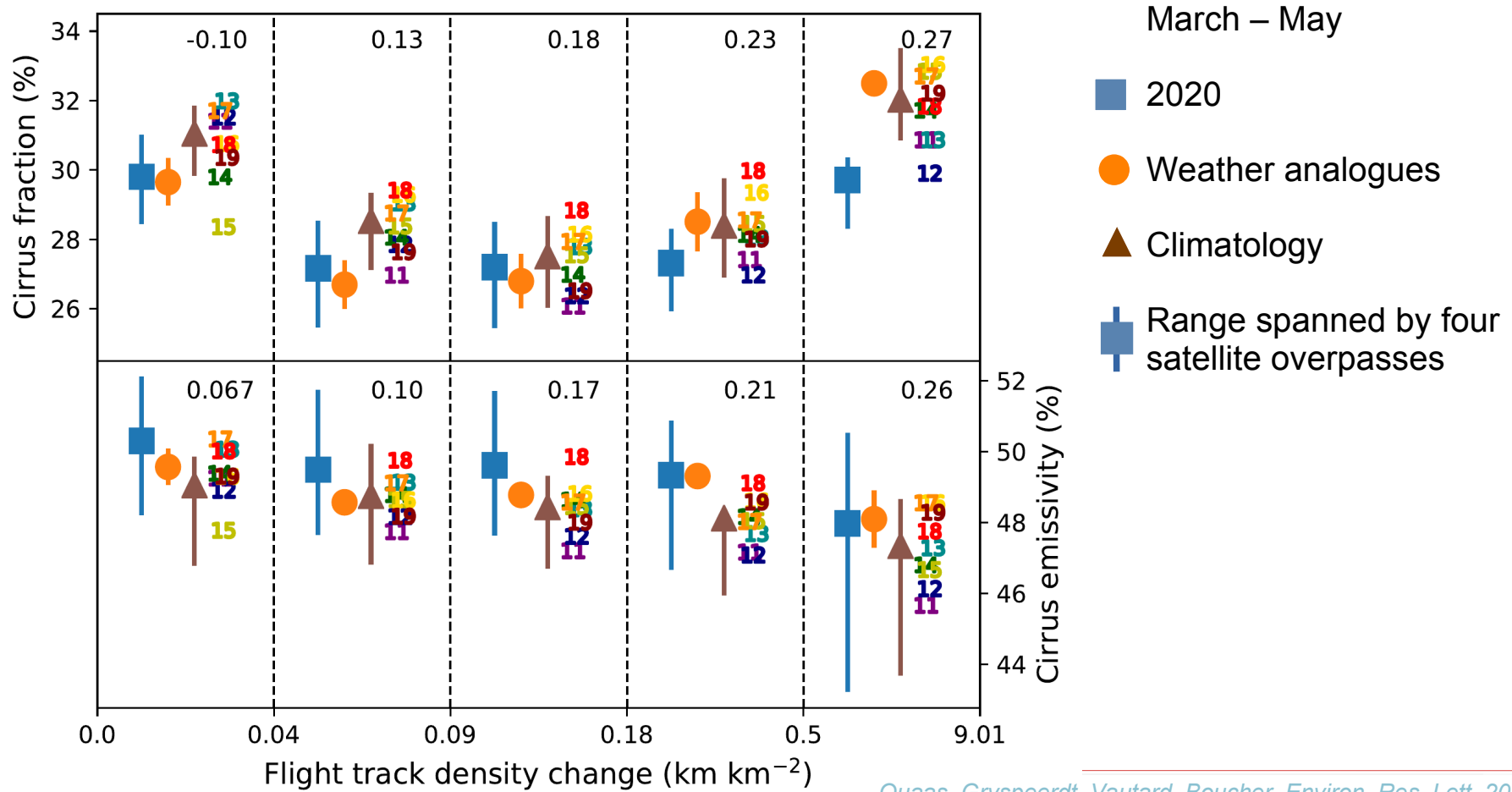
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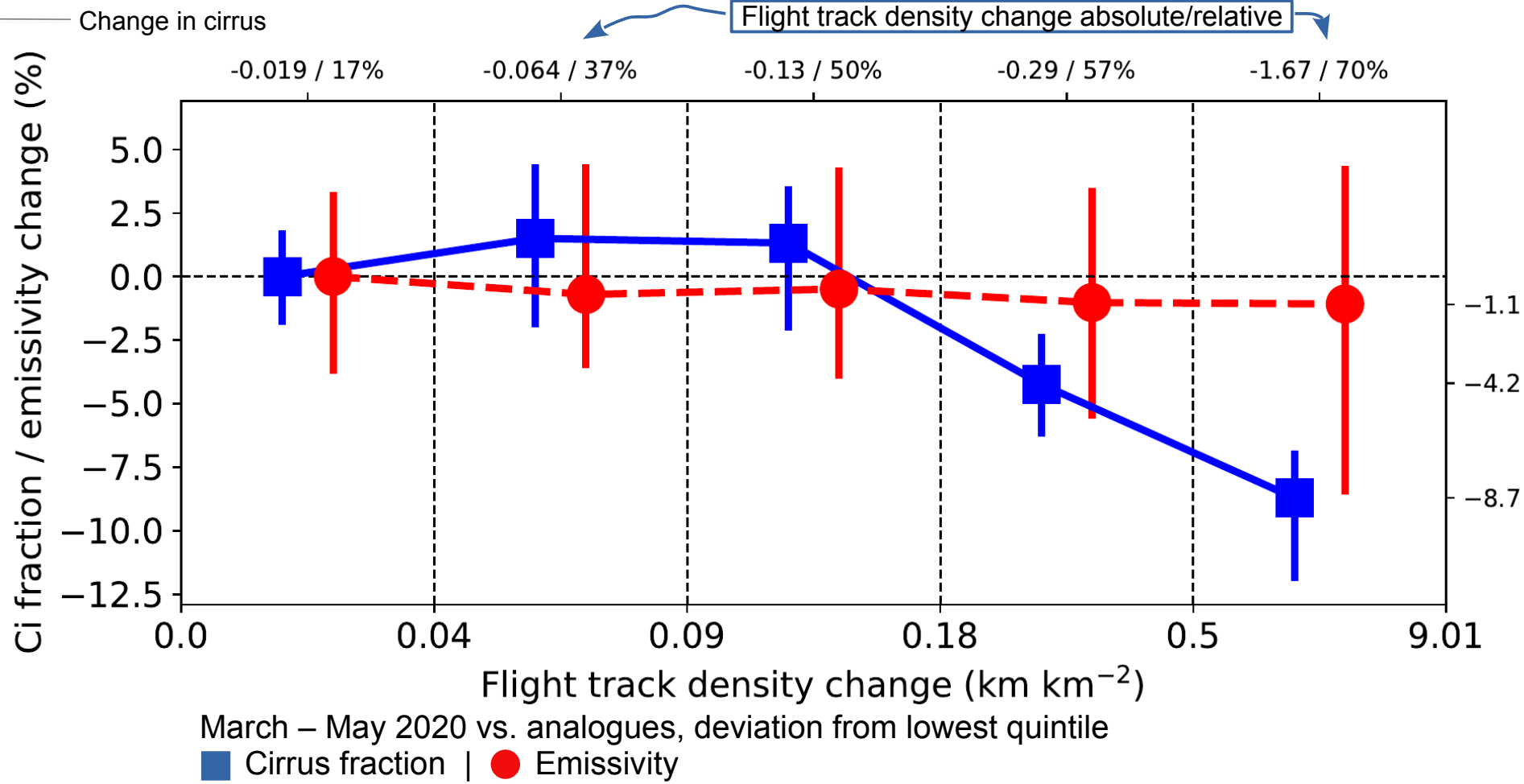
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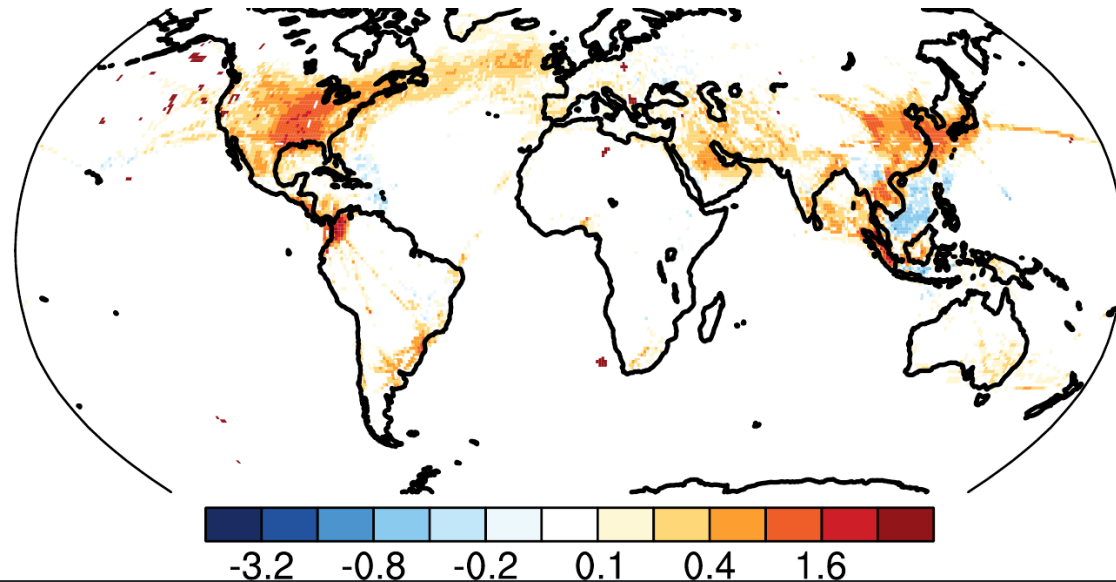


Cirrus fraction & emissivity in regions with air traffic change; 2020 vs. past





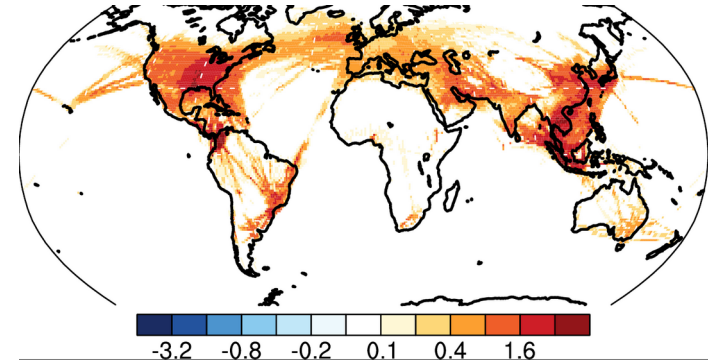
## Implied radiative forcing



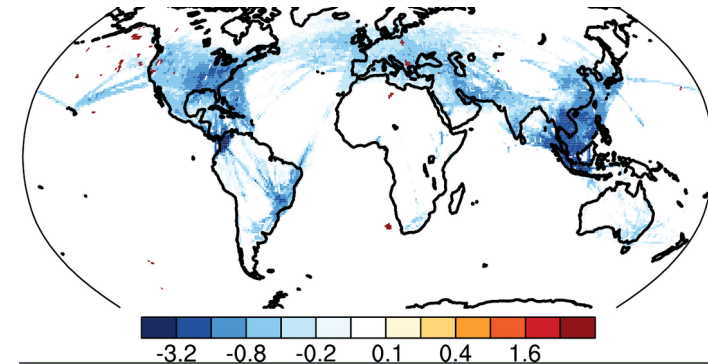
## Net radiative forcing ( $\text{W m}^{-2}$ )

### Radiative forcing

- ECHAM off-line radiation transfer
- driven by ERA5 re-analysis
- accounts for change in aviation during reference period & not-complete reduction in 2020

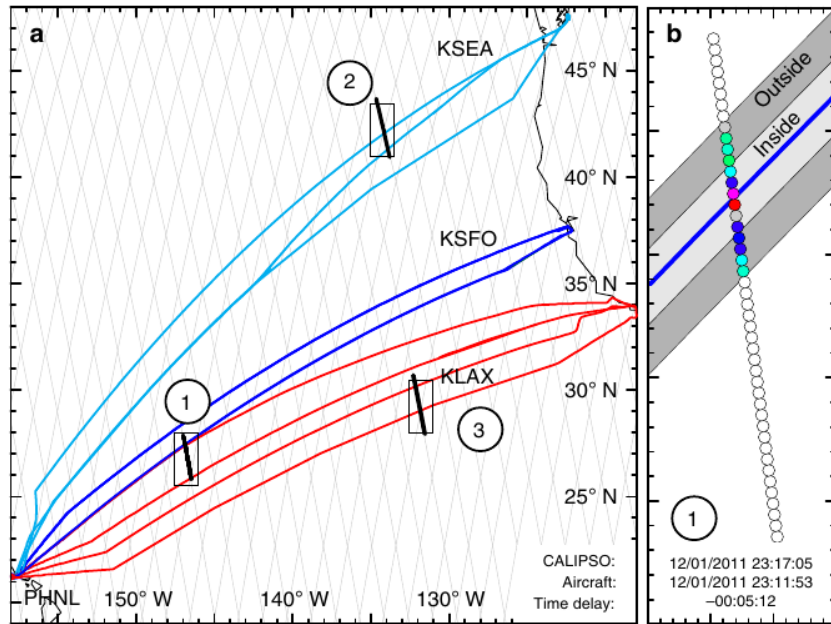


### Terrestrial/long-wave



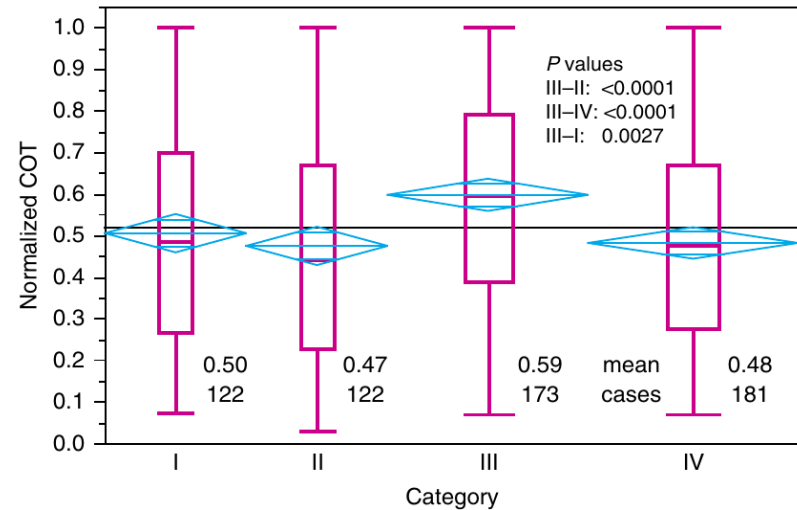
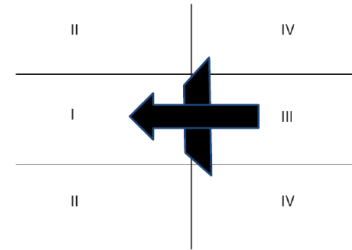
### Solar/short-wave

## Process analysis for individual tracks

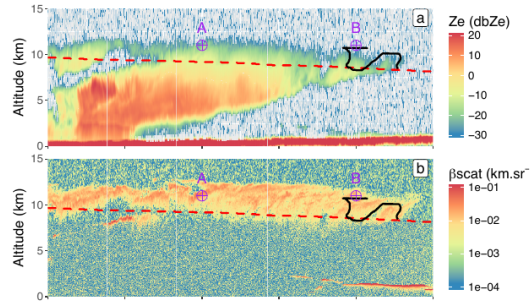


Collocated flight tracks and  
CALIPSO satellite cloud lidar

Compare cirrus affected and unaffected by aircraft  
→ enhancement of cloud optical depth

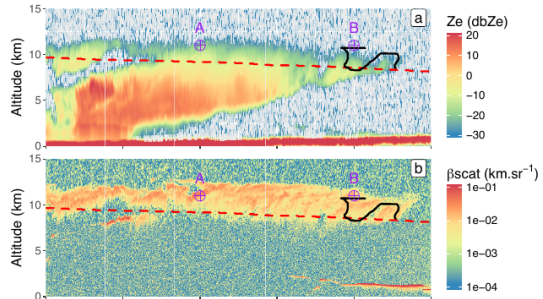


# Satellite retrievals of ice crystal number concentration



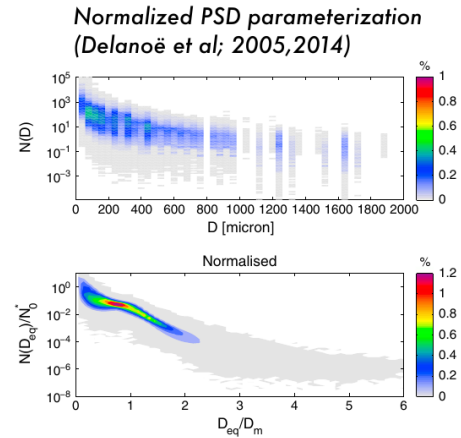
- Lidar backscatter coefficient
- Radar reflectivity factor

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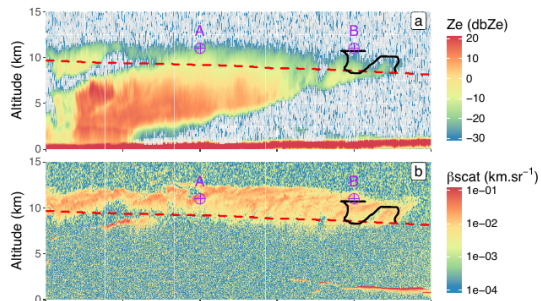


- Lidar backscatter coefficient
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Constrain the moments  
(2nd and 6th)

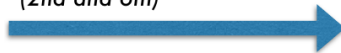


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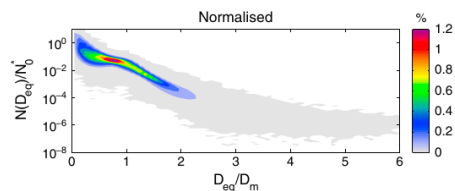
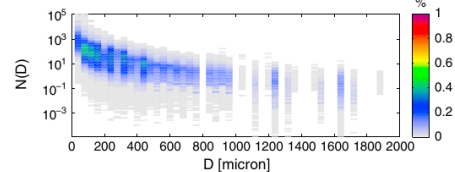


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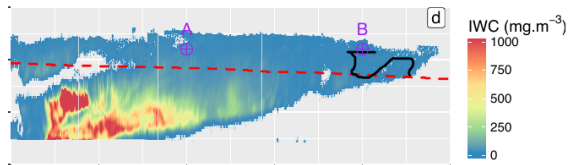
Normalized PSD parameterization  
(Delanoë et al; 2005,2014)



Assumptions:  
mass-D relation, ...

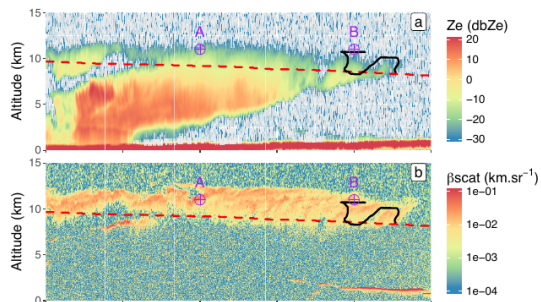


Profiles of IWC, Re, ext



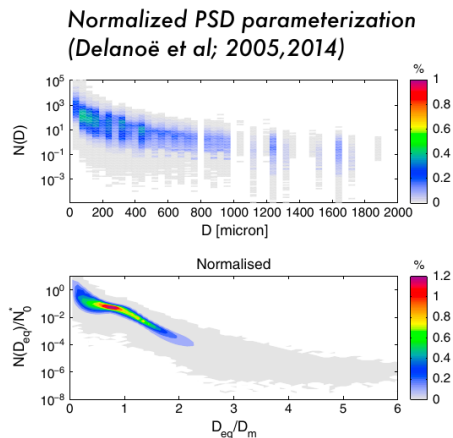
VarCloud / DARDAR

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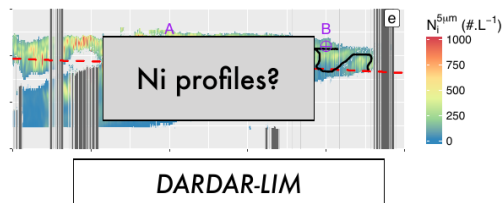


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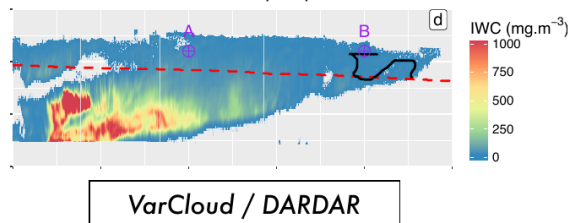
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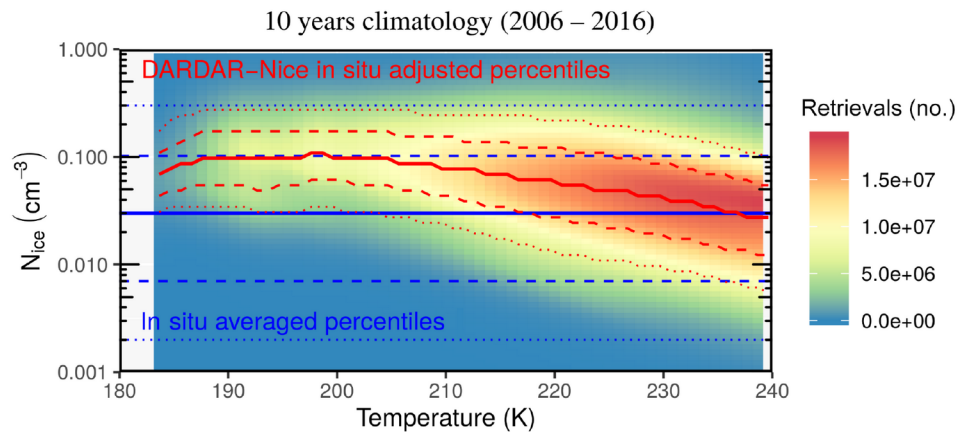
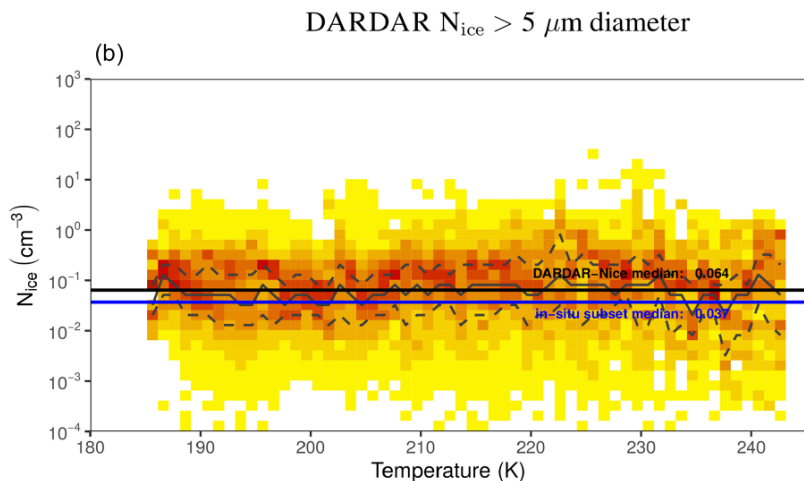
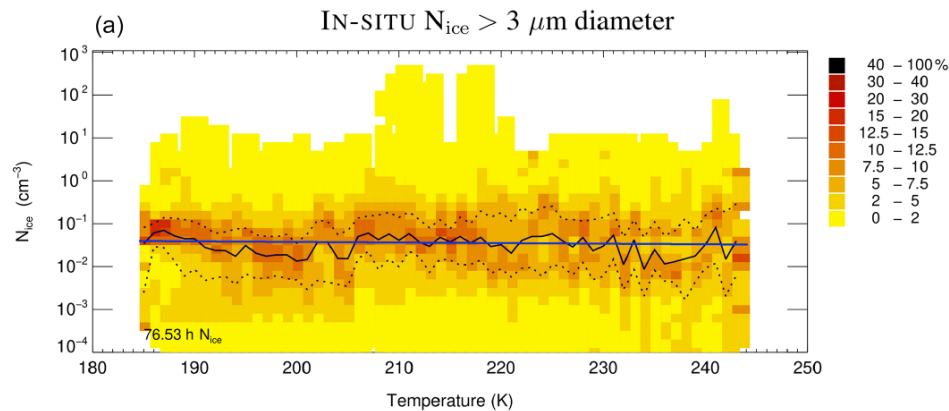


## Conditions to retrieve Ni:

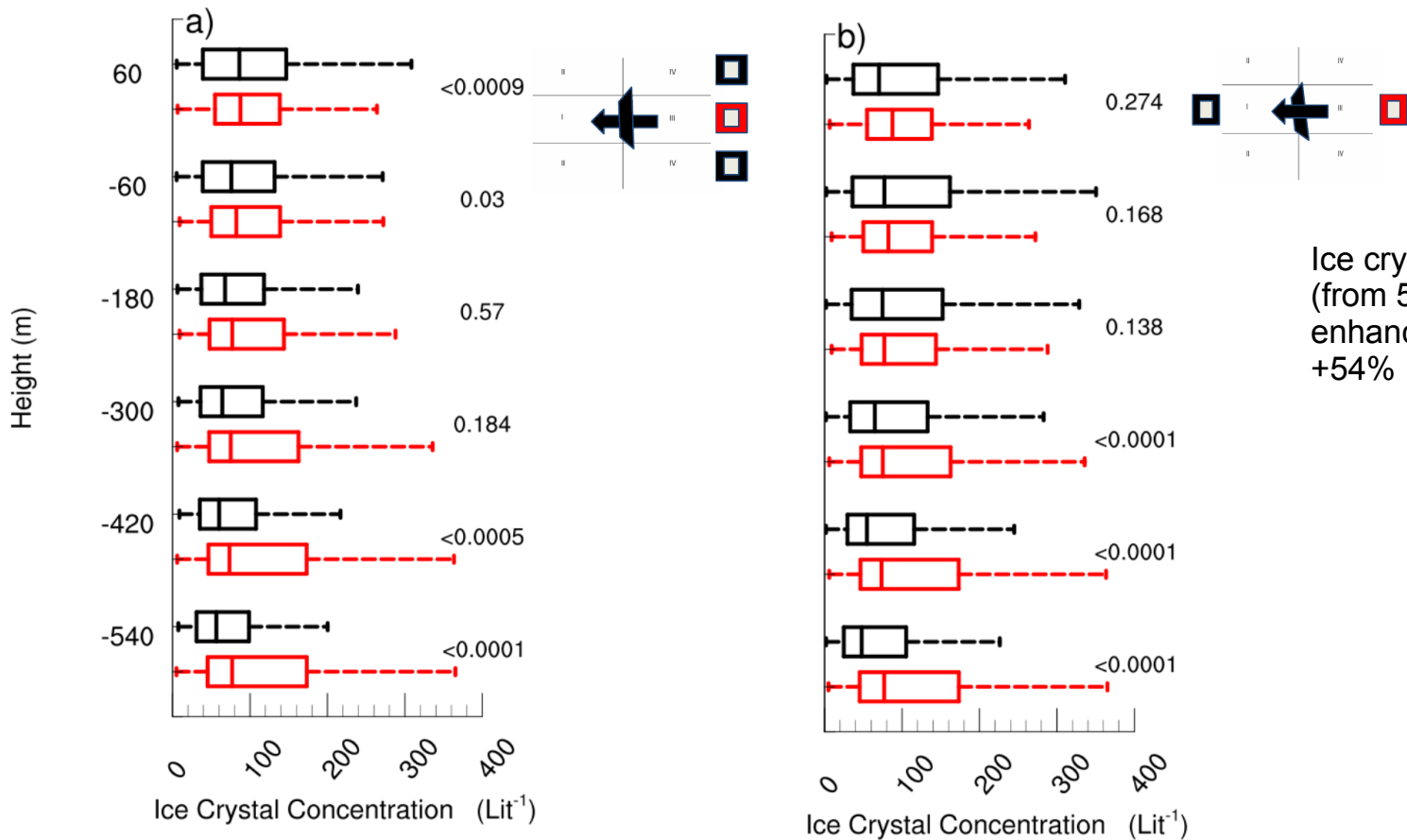
- 1) Can the PSD parameterization used in DARDAR (D05) accurately predict the moment 0?
- 2) Is there enough sensitivity to properly constrain Ni?



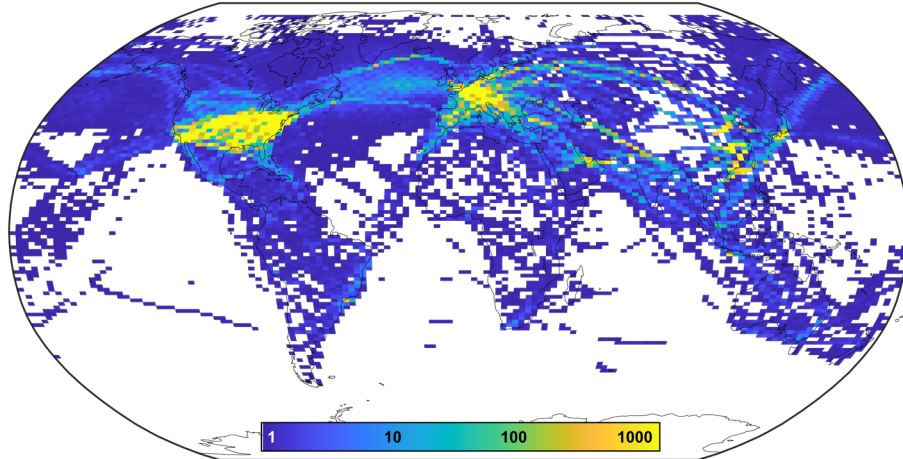
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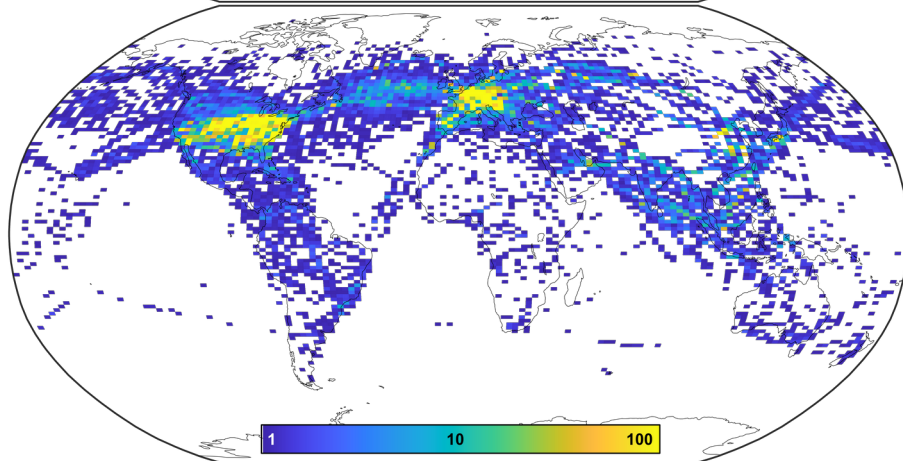
# Ice crystal number concentration enhancement due to aircraft



Ice crystal number concentration (from 5 μm radius upwards) enhanced below the aircraft +54%



Colocation of CALIPSO satellite tracks with aircraft  
(2012, ICAO data)



Cases with cirrus clouds present

### Air traffic reduction during COVID

- March – May 2020 vs. 2019
- minus 80% in large parts of the Northern hemisphere mid-latitudes

### Coincident cirrus reduction

- in regions with large air traffic reduction, 9% cirrus less (absolute) / 17% (relative)

### Radiative forcing: $61 \pm 39 \text{ mW m}^{-2}$ (2019)

- Lee et al. (AR 2020)  $57 (17, 98) \text{ mW m}^{-2}$  for 2018
- IPCC AR6:  $60 (20 \text{ to } 100) \text{ mW m}^{-2}$  for 2019

### Process analysis

- Cirrus optical thickness enhanced
- Ice crystal concentration is enhanced by ~50% below the aircraft