# Satellite-based estimate of the climate forcing due to aerosol - ice cloud interactions

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# Motivations and context

- The contribution of ice and mixed-phase clouds to the global effective radiative forcing associated with aerosol - cloud interactions (aci) remains poorly quantified (Bellouin et al, 2019).

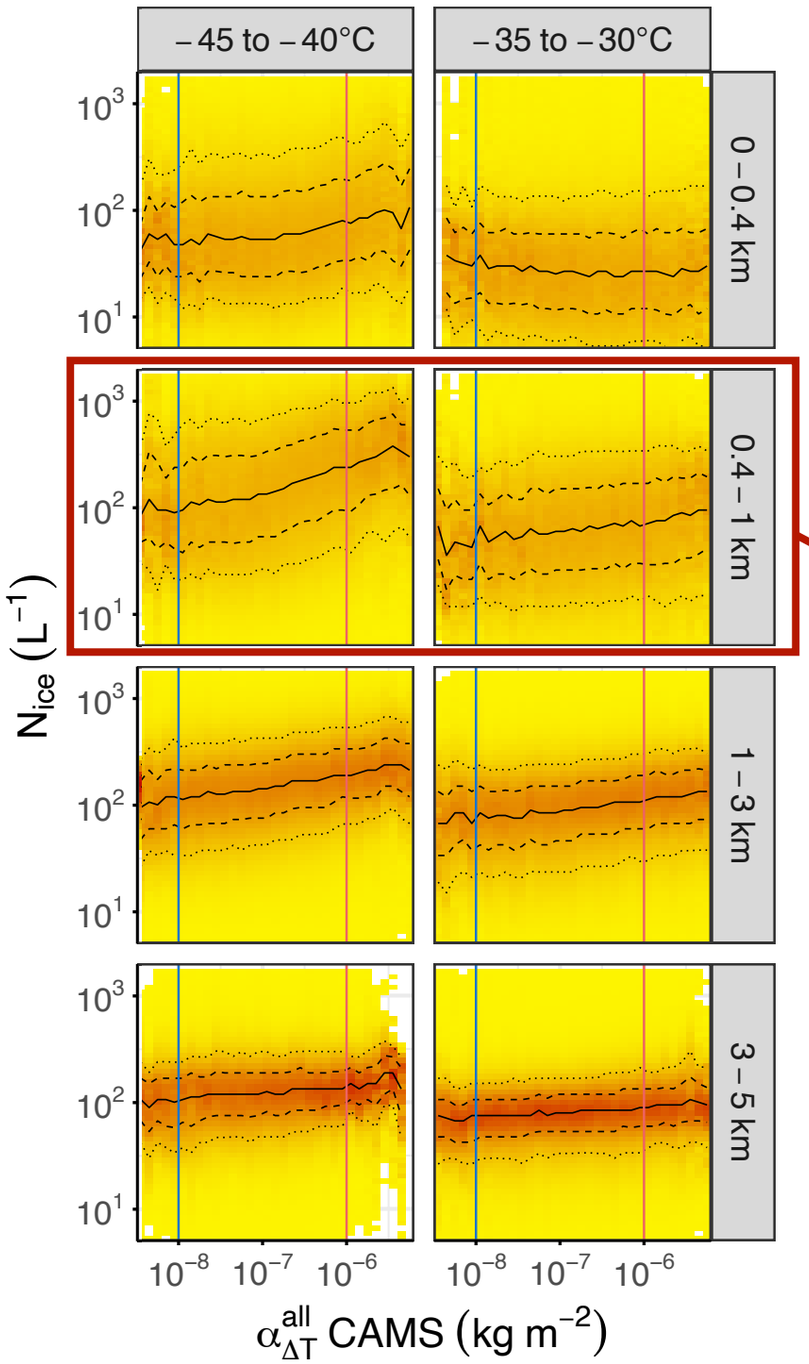
- These uncertainties are largely due to countless challenges faced to represent ice cloud processes and properties in models as well as in retrieval algorithms.

- This study aims to understand the sensitivity of ice cloud properties to aerosols based on a combined observation - reanalyses framework and estimate the subsequent effective radiative forcing due to aerosols - ice cloud aci.
  - The ice crystal number concentration (Ni) is provided space-borne lidar-radar measurements (DARDAR-Nice; Sourdeval et al, 2018)
  - Profiles of aerosol mass mixing ratios along provided along the satellite track by the Copernicus Atmosphere Monitoring Service (CAMS) reanalysis product.

- The presentation will only focus on the sensitivity of Ni to the total aerosol mixing ratio, for different cloud regimes.

# Sensitivity of Ni to aerosols

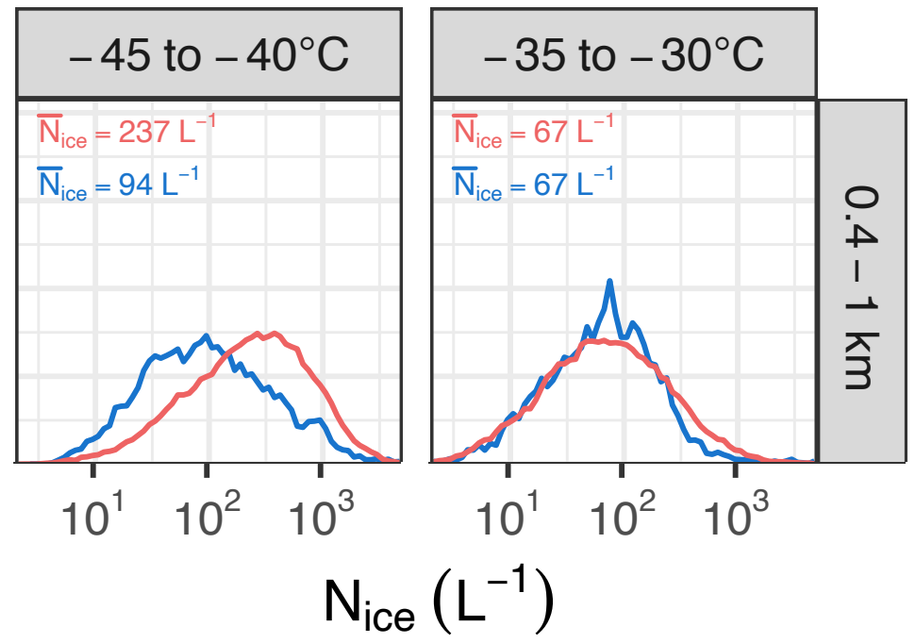
- Ni-aerosol sensitivities are computed for different cloud regimes (IC-CIR; Gryspeerdt et al, 2018), and are additionally binned by season, region, in-cloud temperature and distance from cloud-top.




*Conditional Ni distribution per aerosol mass bin for two temperature ranges (columns) and distance from cloud top. The median is indicated by a plain black line. This figure focuses on Mid-lat North frontal clouds in DJF.*

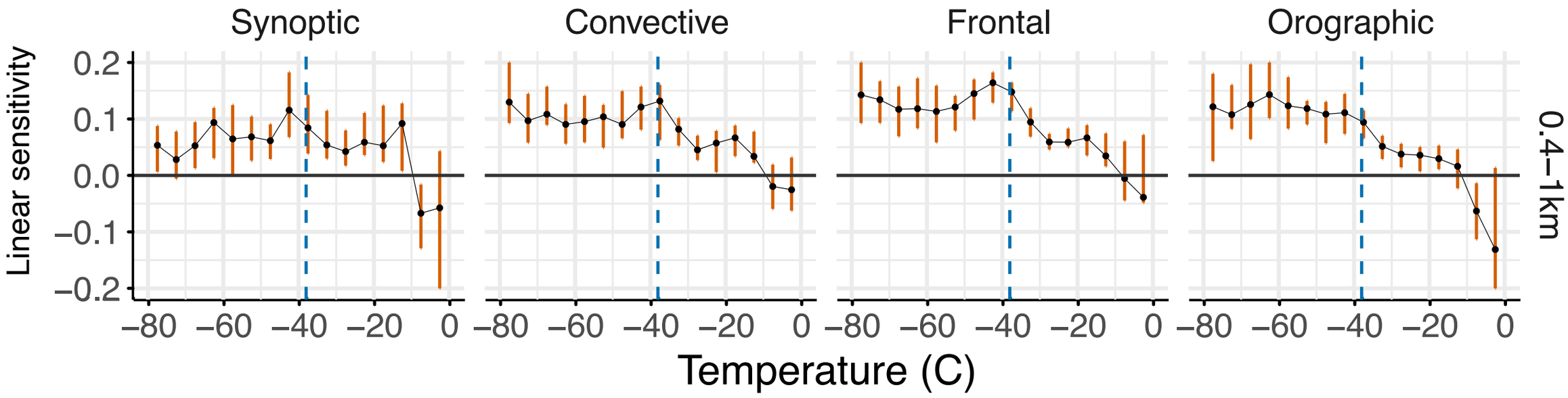
- An overall **positive relationship** between Ni and the aerosol mass is found, particularly at temperatures where homogeneous nucleation dominates.
- The sensitivity of Ni to aerosols is stronger **near** but not at **cloud top**, where sublimation via mixing could limit nucleation.

Blue: clean
Red: polluted




*Sourdeval et al (in prep)*

- When averaged over all regions and seasons, these results are confirmed:



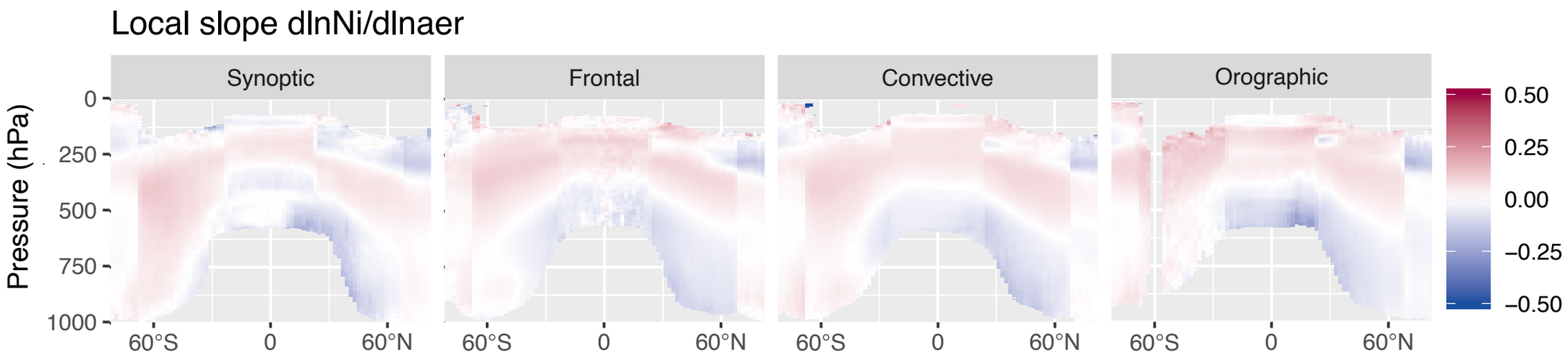

*Linear sensitivity d lnNi / dln aer near cloud-top as function of temperature, for four main cloud regimes. Black dots indicate the mean and orange bars the inter quartile range around it.*

- A notable increase in the Ni-aer sensitivity is typically observed just below -40°C, hinting to a stronger efficiency of the homogeneous freezing.

- The Ni-aer relation decreases with decreasing temperatures for synoptic (in-situ origin) clouds. In more updrafts-driven cloud types it remains stable.

- The sensitivity is much smaller for temperatures warmer than -40°C, becoming negative close to 0°C for all cloud types. This behaviour becomes stronger at deeper levels in the cloud layer.

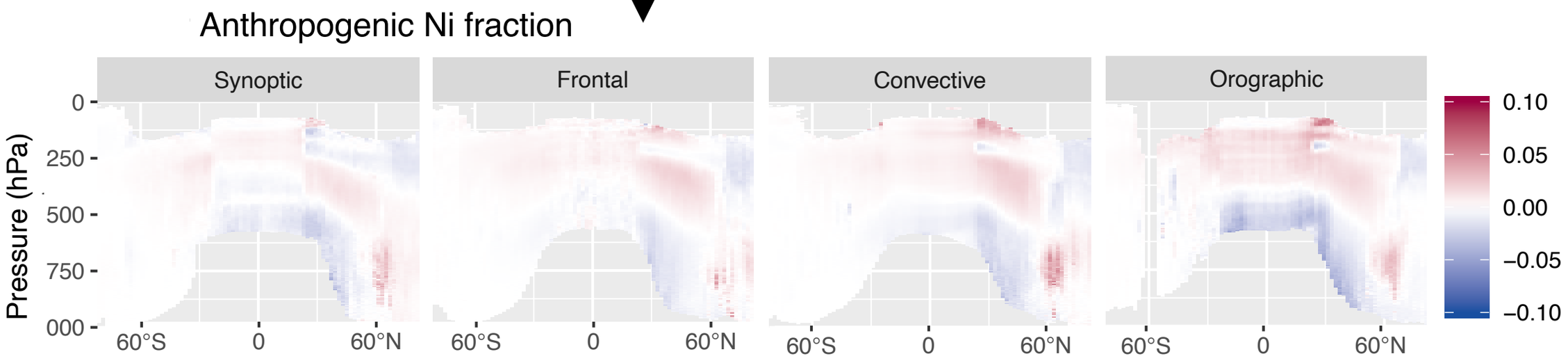
- Zonal means of the sensitivity of Ni to aerosols for two years of A-Train data:




- As expected, an overall increase of Ni with aerosols clearly noted for most cloud types above the hom. freezing threshold, except in the Arctic, and Mid-lat North for synoptic clouds.

- Deeper in clouds, or at warmer temperatures, the sensitivity overall turns negative except in the Mid-lat South.

Combining these results to aerosol anthropogenic fraction estimates (here from CAMS free-running analyses) lead to global Ni anthropogenic fractions of the order of 10%.



# Conclusion & Discussion points

- Combined observation - reanalysis dataset is here used to compute the sensitivity of the ice crystal number concentration to aerosols.

- An overall positive sensitivity is observed for most cloud regimes where  hom. Nucleation processes dominate. Decreases of Ni with an increase of the aerosol mass are noted at warmer temperatures.

- These results, in combination to Ni-IWC sensitivities, are then used to compute the effective radiative forcing related to ice cloud - aerosols interactions (not presented here, contact corresponding author for further discussion).

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- However, large uncertainties and open questions remain concerning the understanding of the observed sensitivities, even regarding their signs.

- The accuracy of the aerosol mixing ratio at high altitudes (i.e. far from the source) also might be questionable. Any inputs on their accuracy or evaluation studies are welcome.