A New Global Aviation Emission Inventory for Contrail-Processed Aerosols

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Background

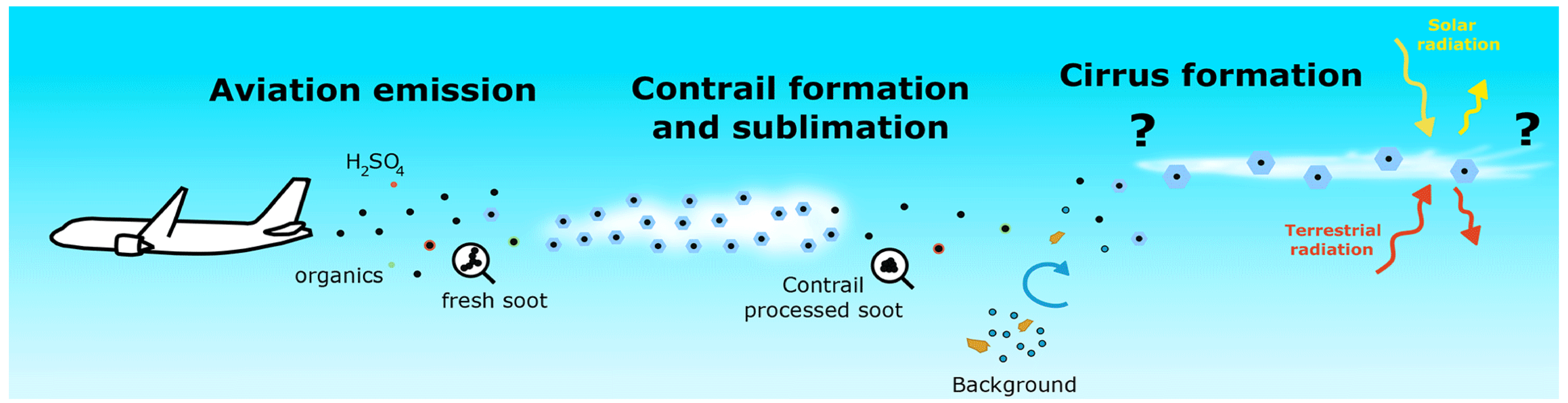

Figure 1. Schematic illustration of the contrail processing. Source: Testa et al. (2024).

- Currently, there are **no best estimates** for the climate impact of aviation's aerosol-cloud interactions. A key challenge lies in aviation **soot particles**' (non-volatile Particulate Matter) ability to act as ice-nucleating particles (INPs), with RF estimates ranging from **-500 to 300 mW/m²** (Lee et al., 2021).
- Experimental research shows that **contrail processing** (Fig.1) can alter the structure of aerosol particles, potentially **enhancing their ice nucleation efficiency** through mechanisms like pore condensation and freezing (PCF; Mahrt et al., 2020).
- However, a comprehensive aircraft emission inventory which includes contrail-processed aerosol particles is lacking.

Method

- This study is based on the work of **Teoh et al. (2023)**, which used **GAIA**, a high-resolution aircraft emissions inventory, and the **CoCiP** contrail simulation model.
  - **GAIA** (Global Aviation Emissions Inventory based on ADS-B) developed by Teoh et al. (2024):
    - Real-life ADS-B aircraft data from 2019 to 2021
    - Aircraft-specific emission characterisation
    - Advanced nvPM emissions estimation
  - **CoCiP** (Contrail Cirrus Prediction) model developed by Schumann (2012):
    - GAIA and ERA5 as input data
    - Models contrail formation and lifecycle based on nvPM emissions and atmospheric conditions
    - Tracks contrail evolution using a Gaussian plume model
- For the contrails simulated by the CoCiP, each contrail ice crystal has an nvPM particle as its core. Thus, according to the definition of contrail processing, the number of contrail ice crystals is equivalent to the nvPM number processed by contrail.

Results

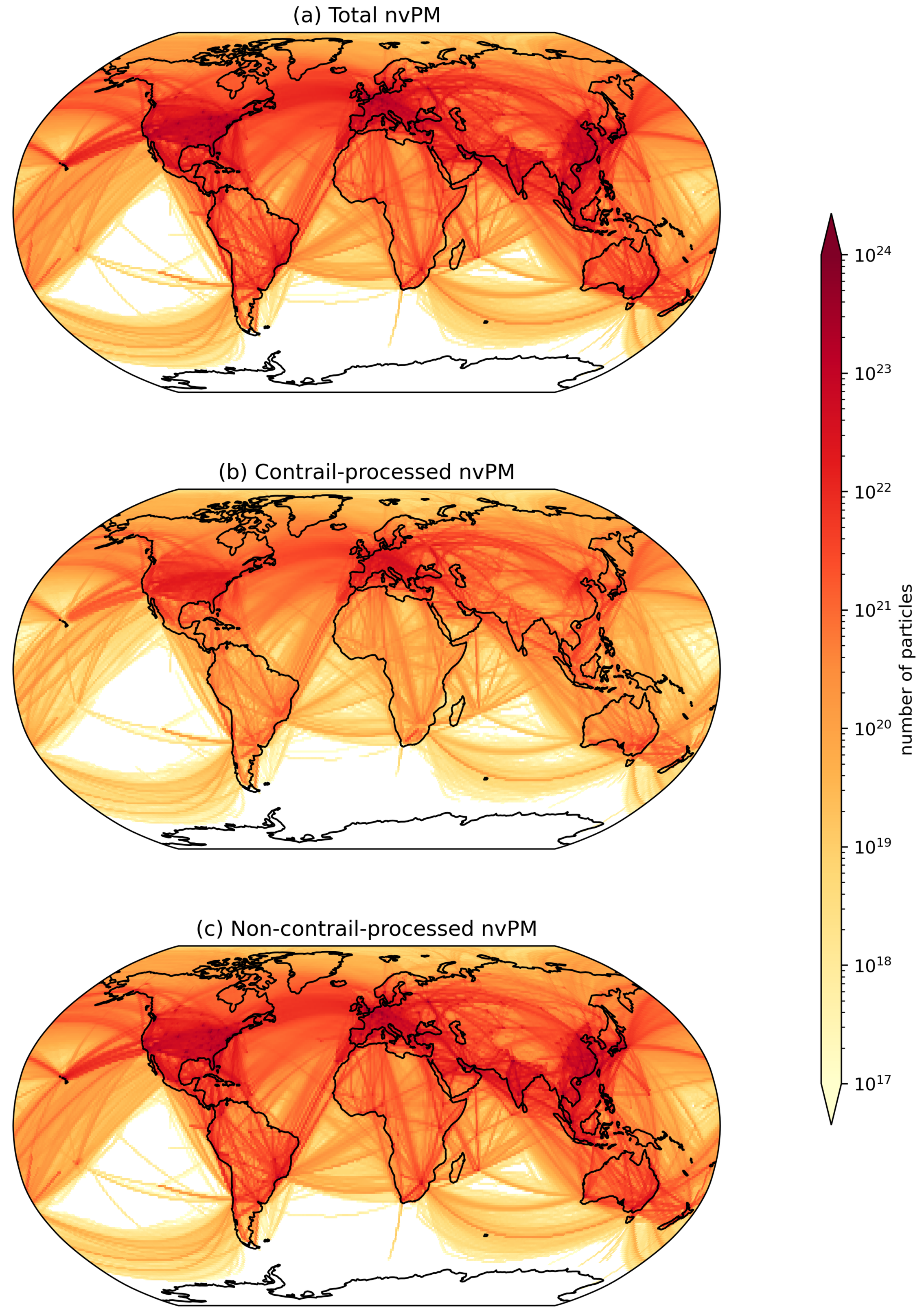

Figure 2. Spatial distribution of a) total, b) contrail-processed, and c) non-contrail-processed nvPM particles emitted by aircraft in 2019 (summed vertically).

- Aviation emitted 2.83 × 10^{26} nvPM particles in 2019, with **reductions of 48% in 2020 and 41%** in 2021 due to COVID-19.
- The annual proportion of contrail-processed particles remained **relatively stable**, decreasing slightly from 15% in 2019 to ~14% in 2020 and 2021.

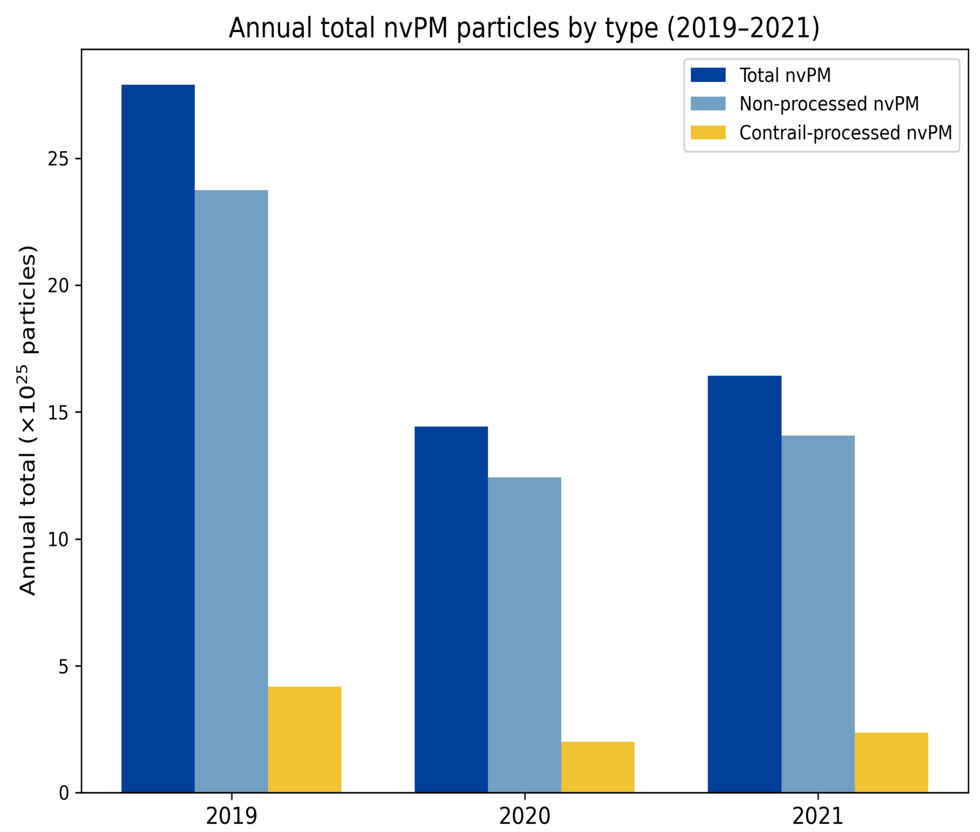

Figure 3. Annual total number of total (dark blue), non-contrail-processed (light blue), and contrail-processed (beige) nvPM particles from 2019 to 2021.Particle counts are in units of 10^{25}.

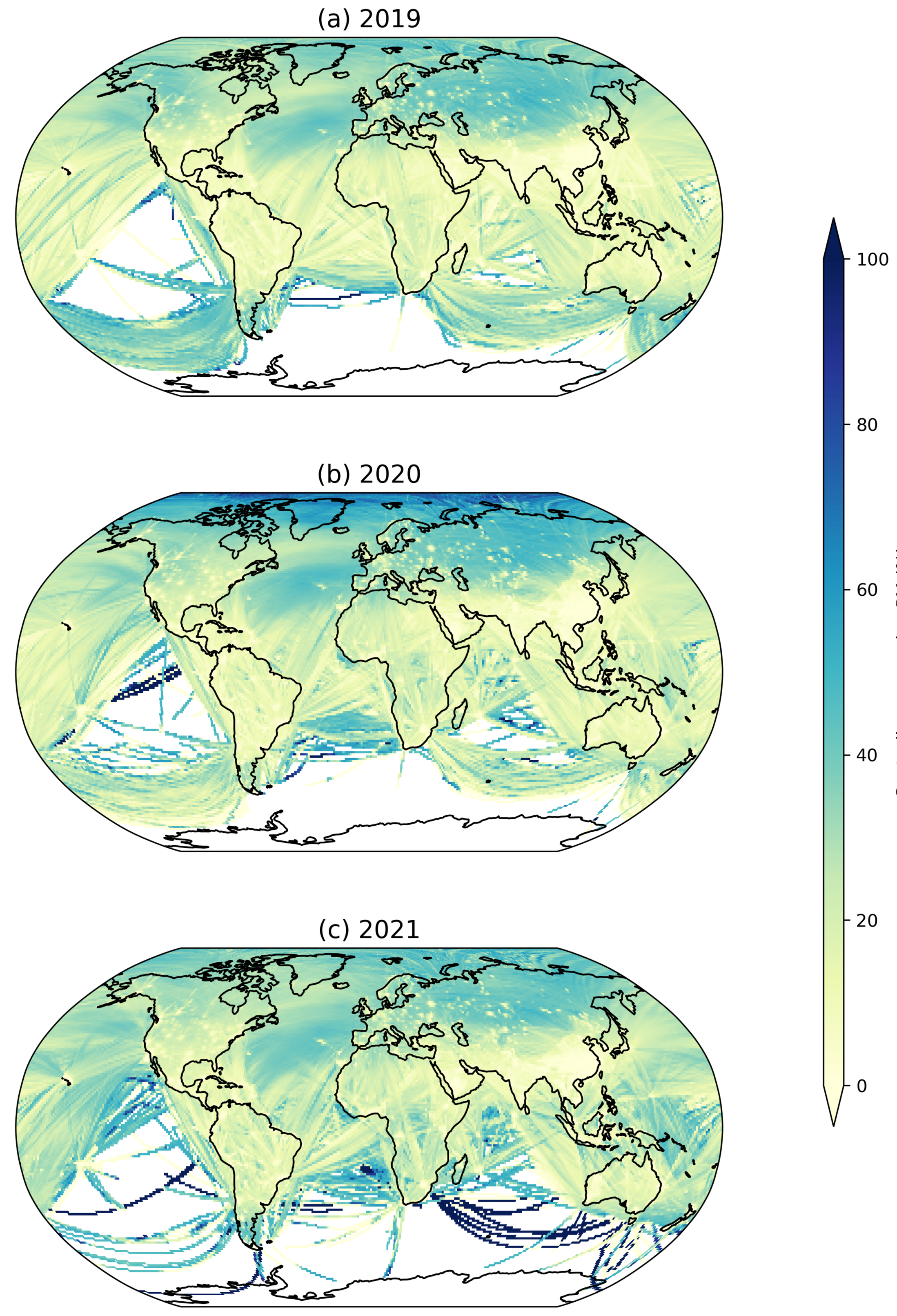

Figure 4. Spatial distribution of contrail-processed nvPM as a percentage of total nvPM, summed vertically for a) 2019, b) 2020, and c) 2021.

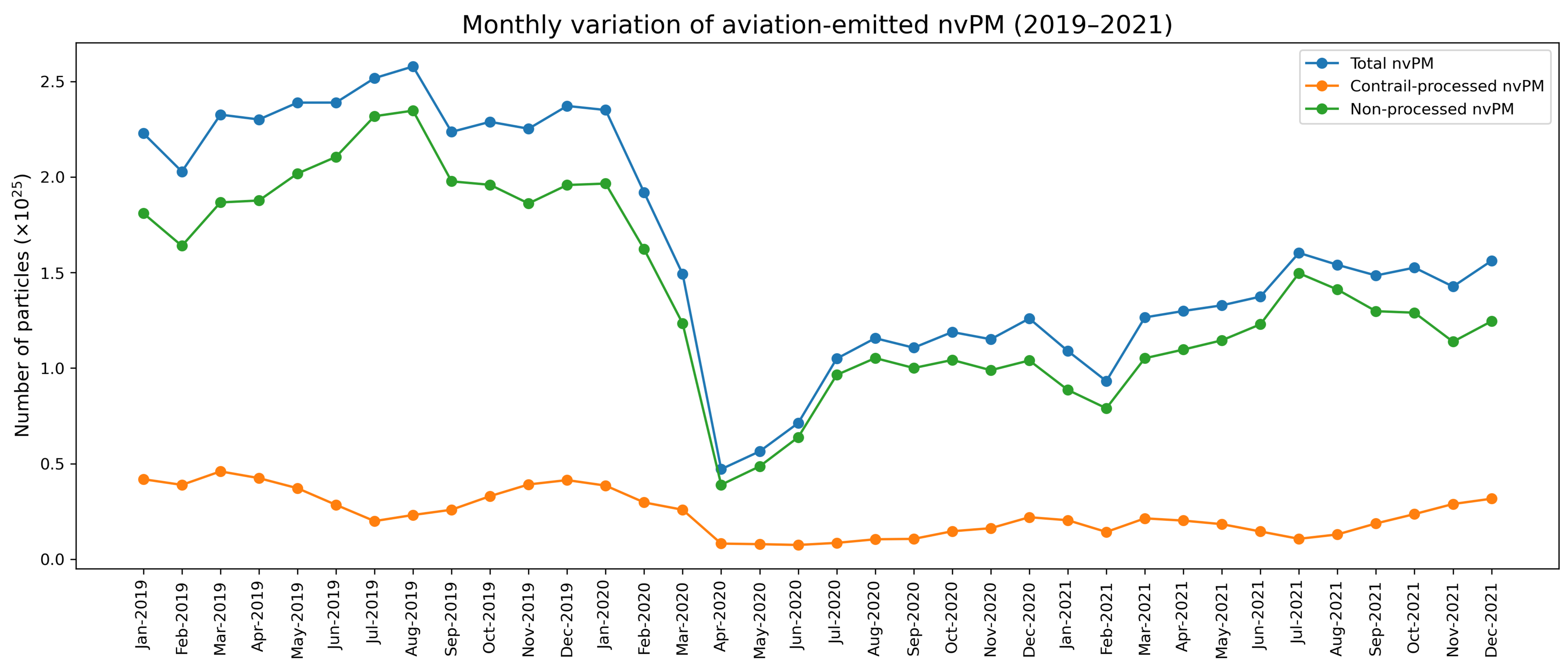

Figure 5. Monthly variations of total (blue), contrail-processed (orange), and non-contrail-processed (green) nvPM particles from 2019 to 2021. Particle counts are in units of 10^{25}.

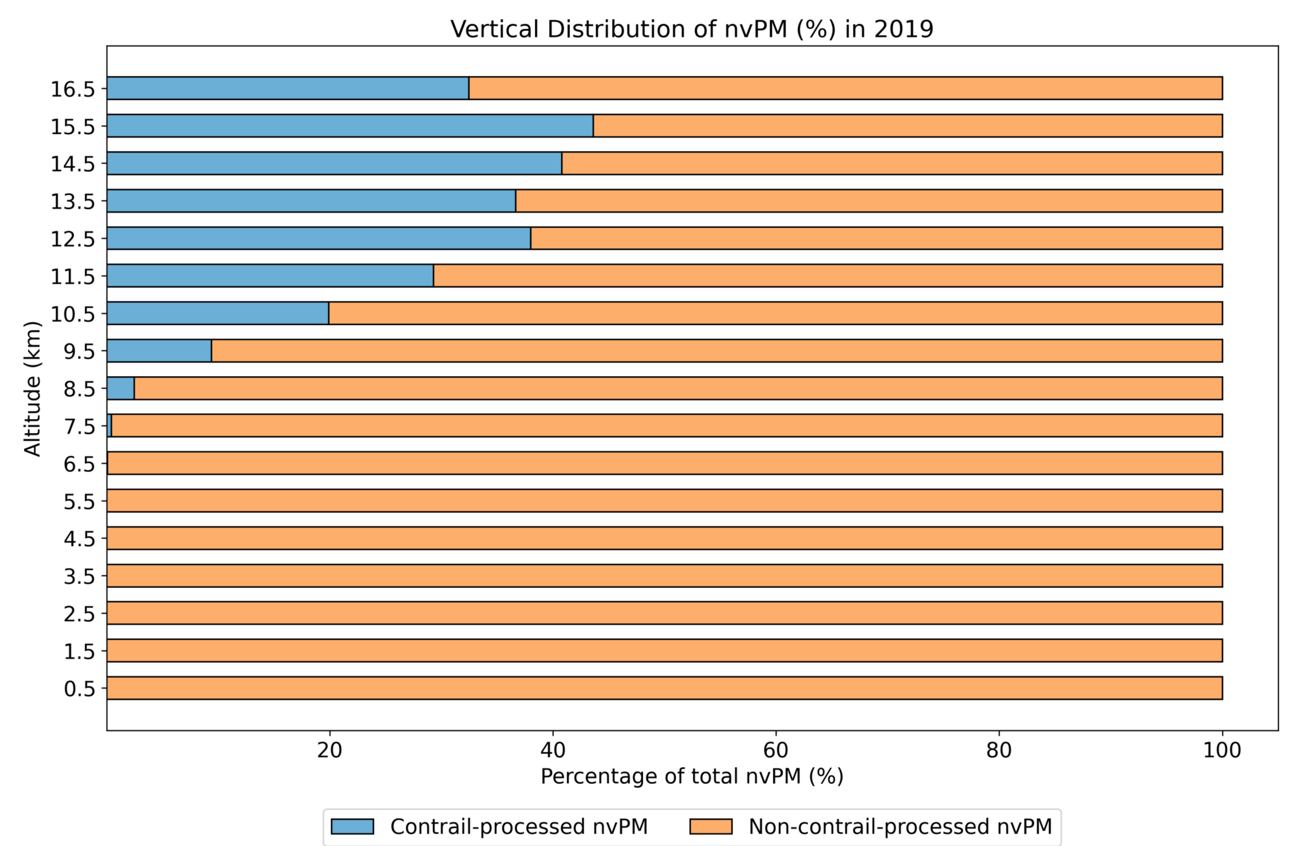

Figure 6. Vertical percentage contribution of global sum contrail-processed (blue) and non-contrail-processed (orange) nvPM to total nvPM in 2019.

Key Reference:

Lee et al. (2021) The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018. Atmospheric Environment, 244, p. 117834.
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