Export of aircraft exhaust ultrafine particles from Tokyo International (Haneda) Airport

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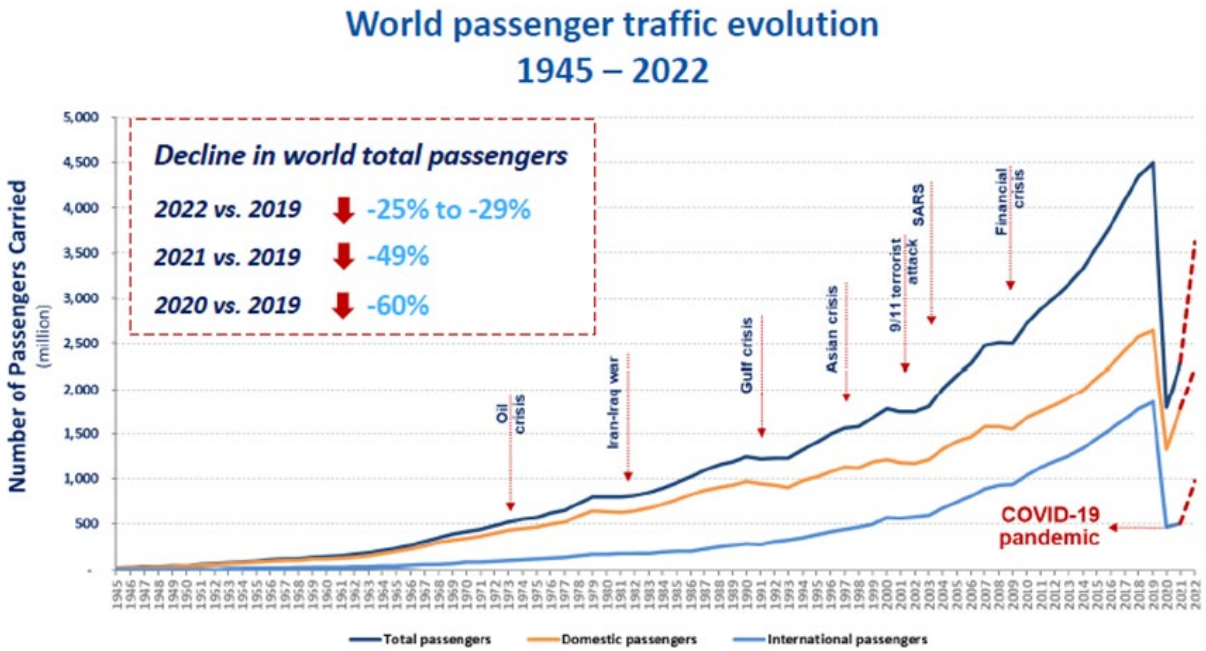
ETH Nanoparticles Conference 2026

June 1, 2026

Growth of civil aviation



ICAO Env. Report, 2022
(https://www.icao.int)

FIGURE 1: World passenger traffic evolution, 1945–2022

- The global passenger market started recovering in 2022 after COVID-19.
- High concentrations of ultrafine particles (UFPs; < 100 nm) have adverse effects on human health.
- Jet aircraft emissions could be significant sources of UFPs around airports.
- Environmental impacts of aircraft emissions continue to be an important issue.

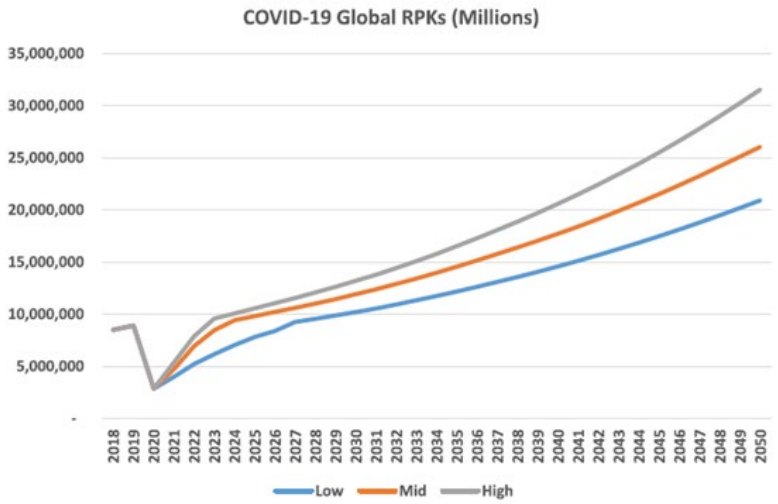


FIGURE 1-1: COVID-19 Global Passenger Forecast Scenarios

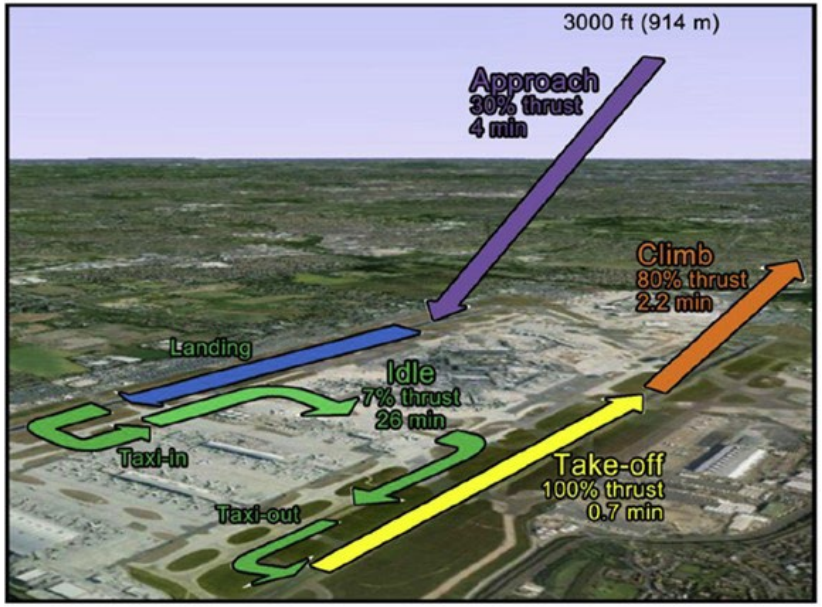
Sources of particles from airports

Masiol and Harrison, 2014

Factors affecting aircraft emissions

- Engine types
- Fuels (sulfur, aromatics)
- Jet engine lubrication oil
- Landing and takeoff (LTO) cycles
- Auxiliary power units (APU)
- Tires and brakes

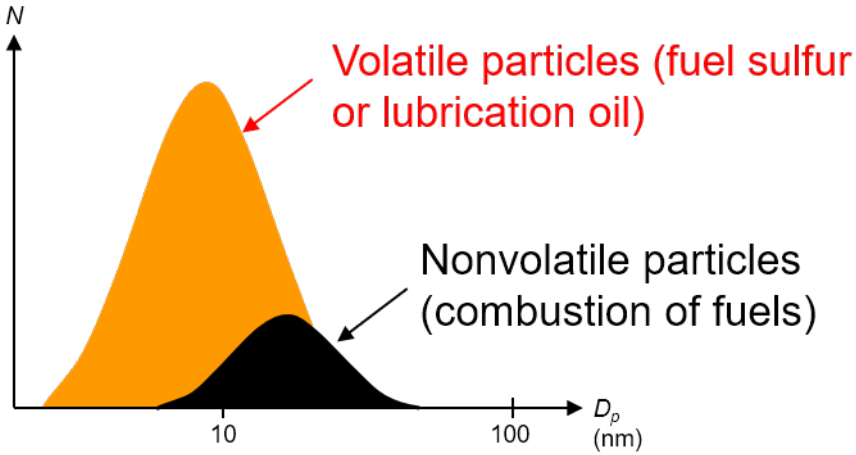
etc.



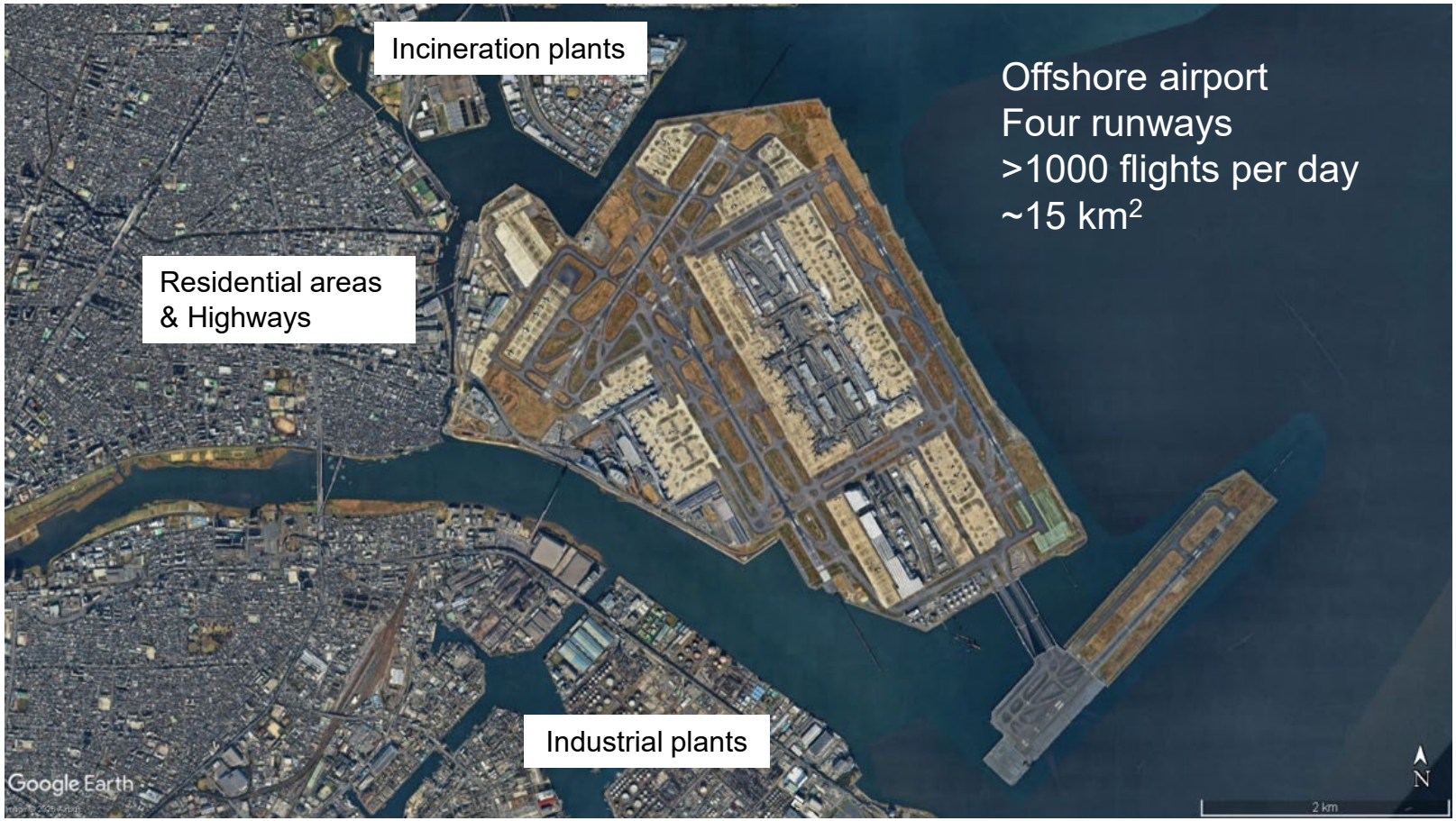
Others

- Trucks and vehicles
- Ground power units (GPU)
- Heat generation

etc.



Haneda Airport (HND)

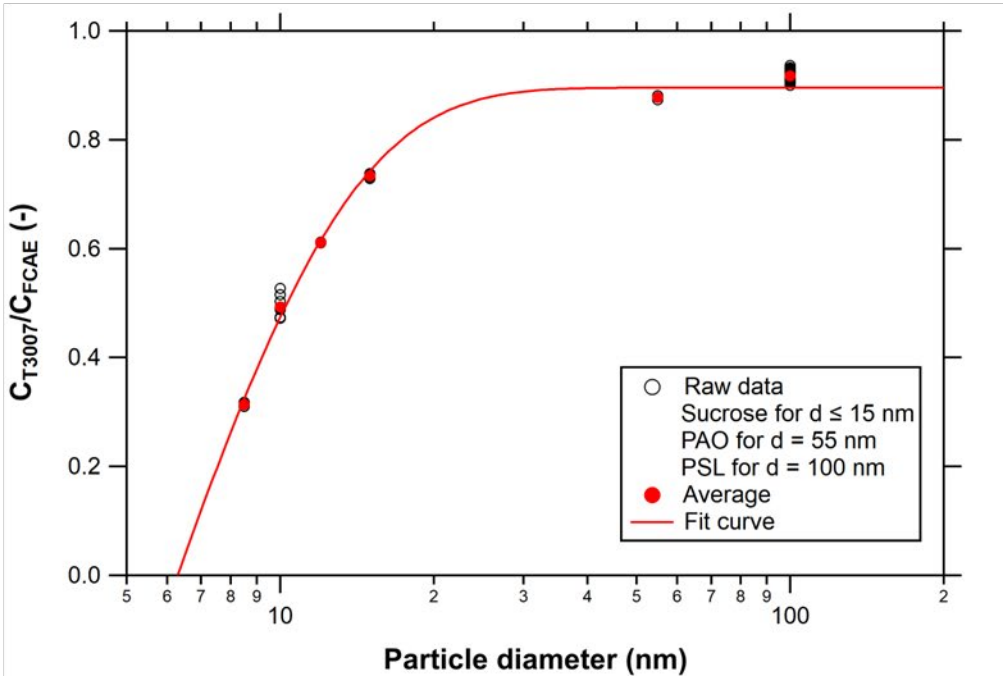


Google Earth (access 2026/5/19)
Legends were added for clarity

- Major airport in Japan, located in the coastal area of Tokyo Bay.
- Impacts of HND emissions on UFPs in Tokyo are poorly understood.
- The purpose of this study was to estimate the number flux of UFPs exported from HND using mobile measurement data and numerical simulations.

Instrumentation

Takegawa, Murashima, and Sakurai, AAQR, 2025
Detailed evaluation at AIST



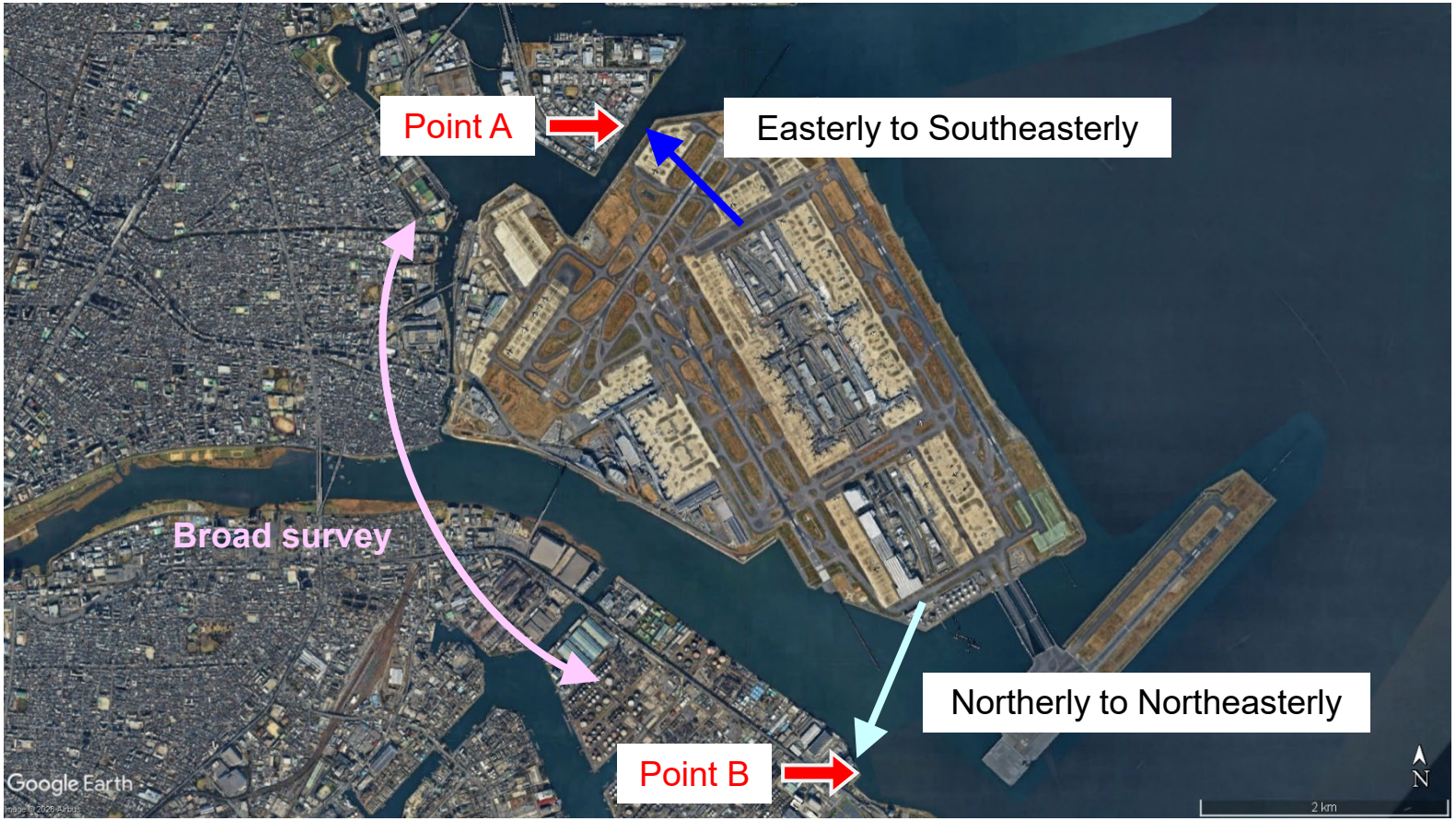
Main instrument: portable CPC (TSI Model 3007)

- Isopropyl alcohol for the working fluid. The nominal d_{50} of 10 nm (N_{10}).
- Non-unity asymptotic detection efficiency and effects of particle coincidence were corrected.
- Field data show that the CPC 3007 underestimates N_{10} with increasing the sub-10 nm fraction.

Other instruments

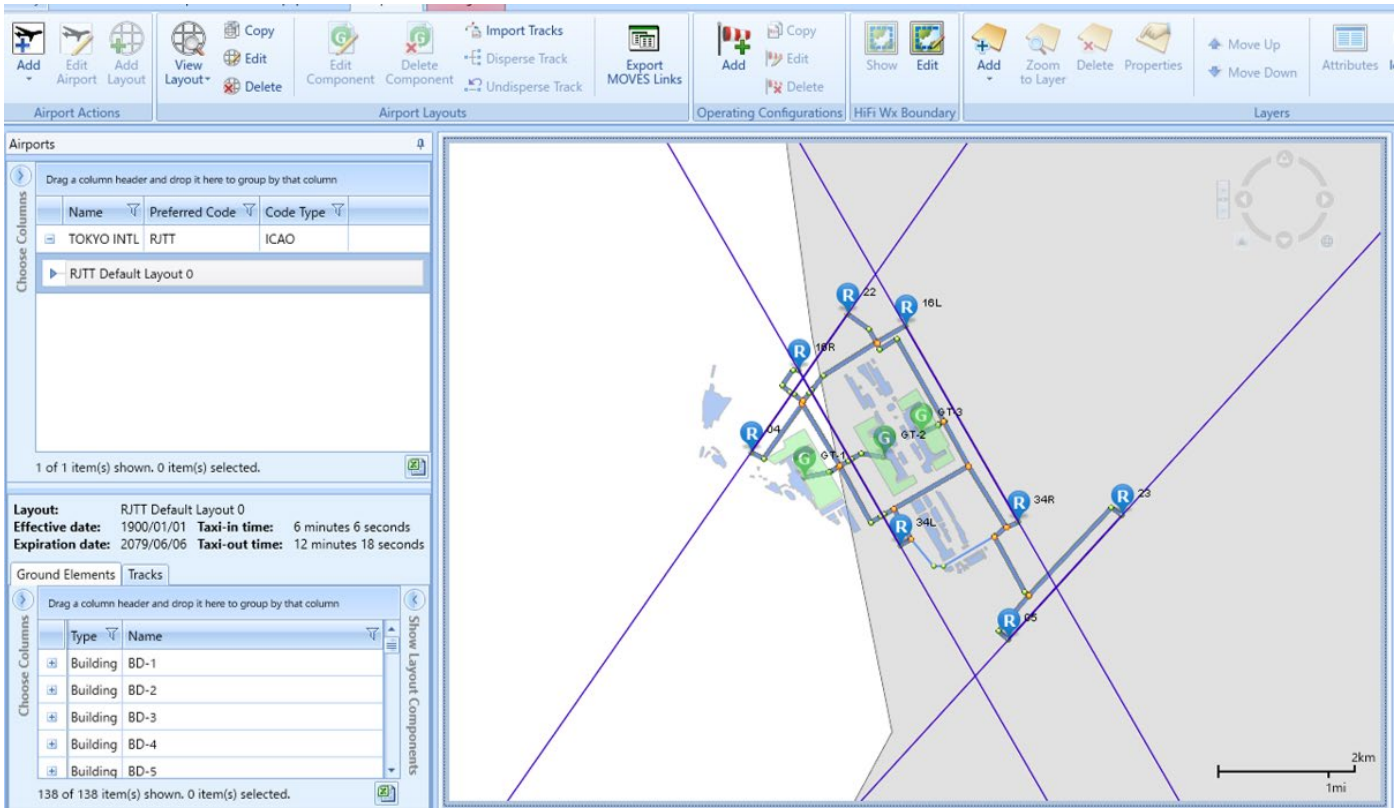
- NanoScan (TSI Model 3910), OPC (Beckman Coulter HHPC 6+), CO_2 sensor (Li-Cor, LI-840)

Mobile measurements



- Total 8 days between 2022 and 2026.
- Measurements in 2022 and 2023 (the combination of the CPC and NanoScan or the CPC only) for broad survey to search for appropriate sampling points.
- Measurements in 2024, 2025, 2026 (the combination of the CPC, HHPC, and CO_2 sensor) for quantitative characterization of aircraft exhaust plumes downwind of HND (points A or B).

Aviation emission model



AEDT (Aviation Environmental Design Tool) https://aedt.faa.gov/

- High-resolution emission mapping of pollutants including CO_2, NO_x, and nvPM.
- Actual flight time schedule was used for the input data (January 2018 as a reference case).
- Delay and sequencing model (DSQM) option explicitly calculates the aircraft movements on the taxiways.
- Auxiliary power units (APU) were included in the simulations. Non-aircraft emissions such as ground support equipment (GSE) were not included (AEDT has this option).

A top-down estimate

A bottom-up estimate of emission rates for X (CO_2 or particles per day):

$$\Phi_{\mathrm{X}} = \sum_{i} \sum_{\mathrm{LTO}} \mathrm{EI}^{\mathrm{X}}_{i,\ \mathrm{LTO}} \times q_{i,\ \mathrm{LTO}}$$

($\mathrm{EI}_{i,\ \mathrm{LTO}}$: emission index; $q_{i,\ \mathrm{LTO}}$: fuel consumption for an aircraft model i for each LTO mode)

For the particle flux (F_{N}) exported from HND, an additional variable, ε, to represent the loss of particles within the HND domain (~15 km^2) should be considered:

$$F_{\mathrm{N}} = \sum_{i} \sum_{\mathrm{LTO}} \varepsilon \times \mathrm{EI}^{\mathrm{N}}_{i,\ \mathrm{LTO}} \times q_{i,\ \mathrm{LTO}}$$

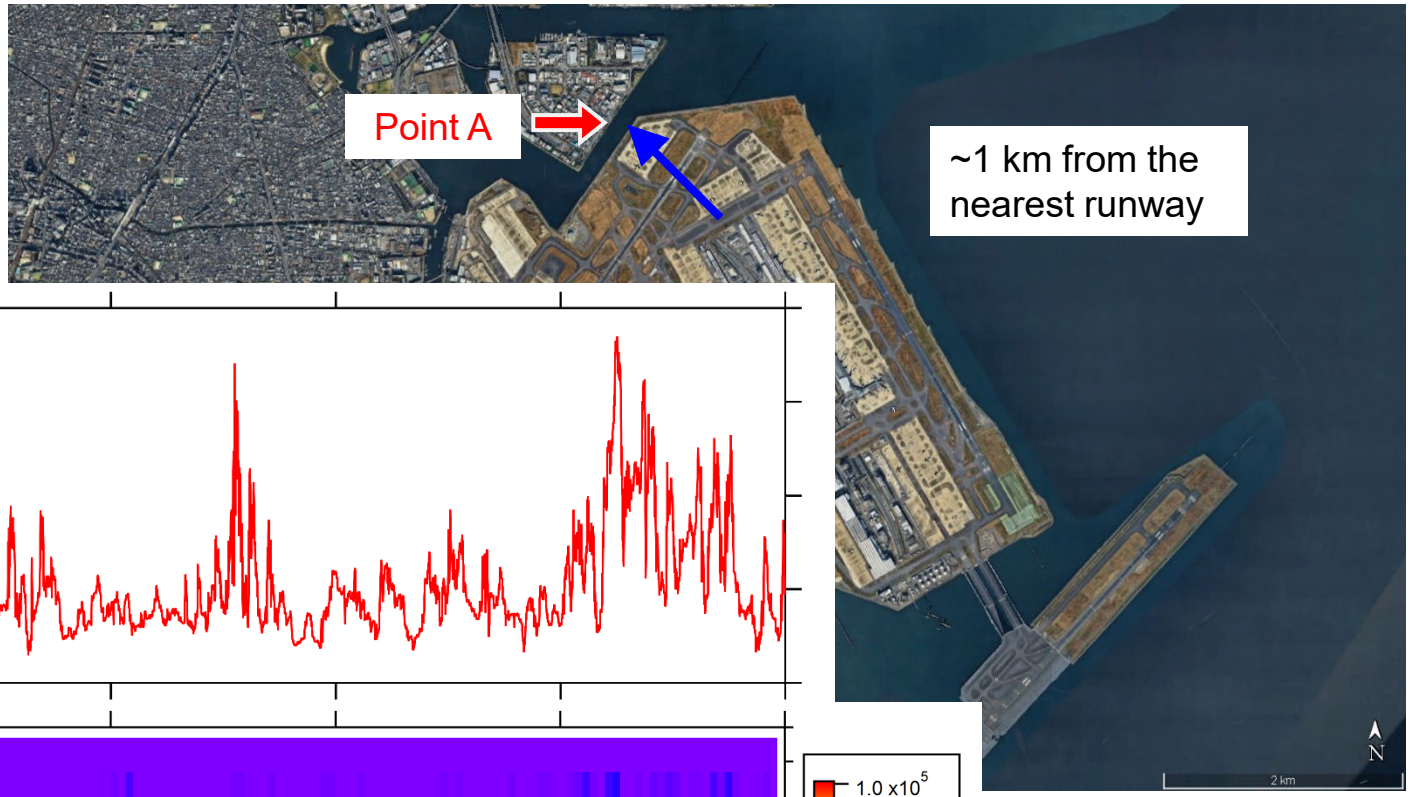
An alternative top-down estimate for particles assuming that the average $\Delta N/\Delta \mathrm{CO}_2$ ratio downwind of HND is proportional to $F_{\mathrm{N}}/\Phi_{\mathrm{CO2}}$:

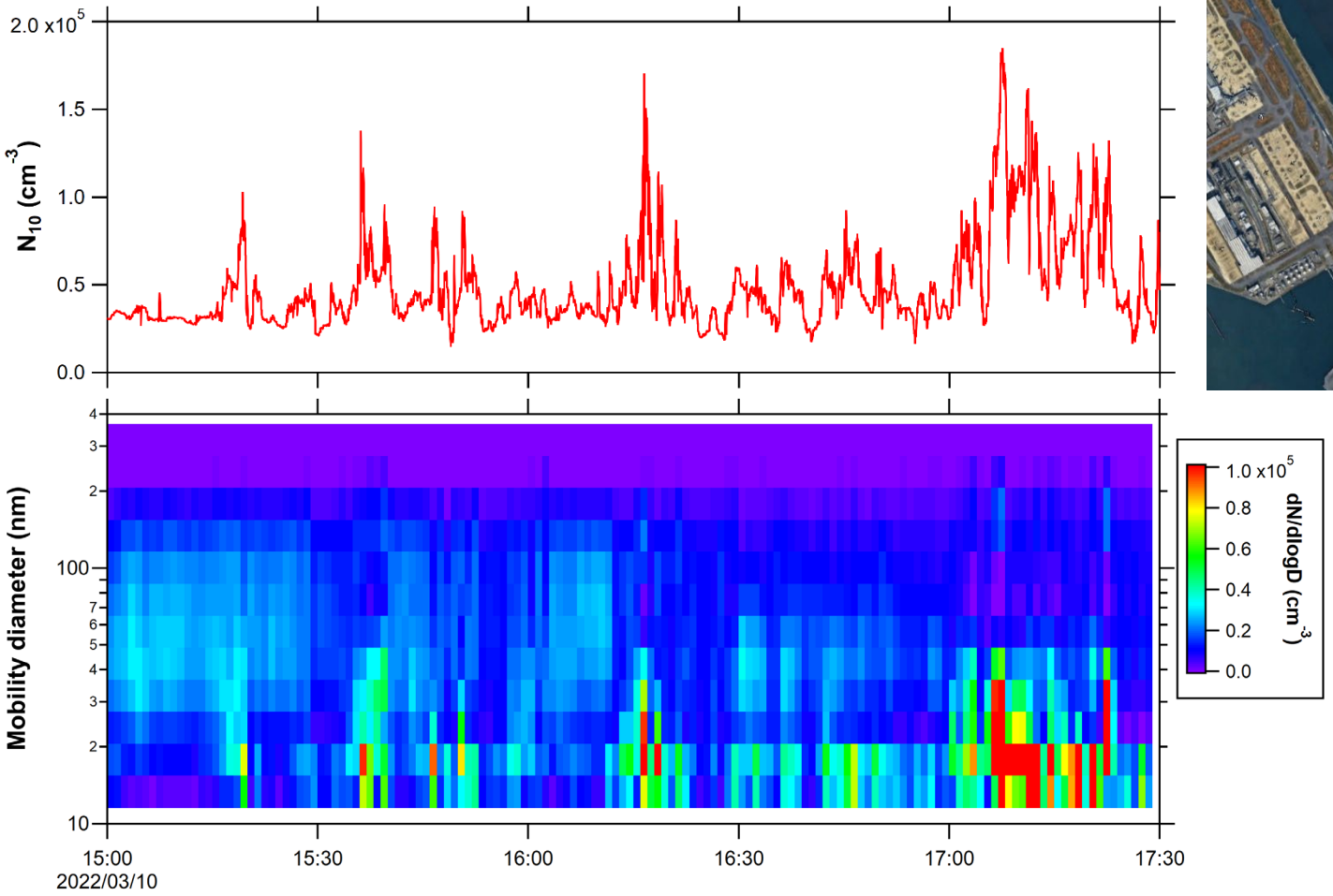
$$F_{\mathrm{N}} = k \left\langle \frac{\Delta N}{\Delta \mathrm{CO}_2} \right\rangle \Phi_{\mathrm{CO2}} = \frac{\widetilde{\mathrm{EI}^{\mathrm{N}}}}{\mathrm{EI}^{\mathrm{CO2}}} \Phi_{\mathrm{CO2}}$$

$\widetilde{\mathrm{EI}^{\mathrm{N}}}$ is the effective particle number EI (spatially and temporally averaged emission and loss).

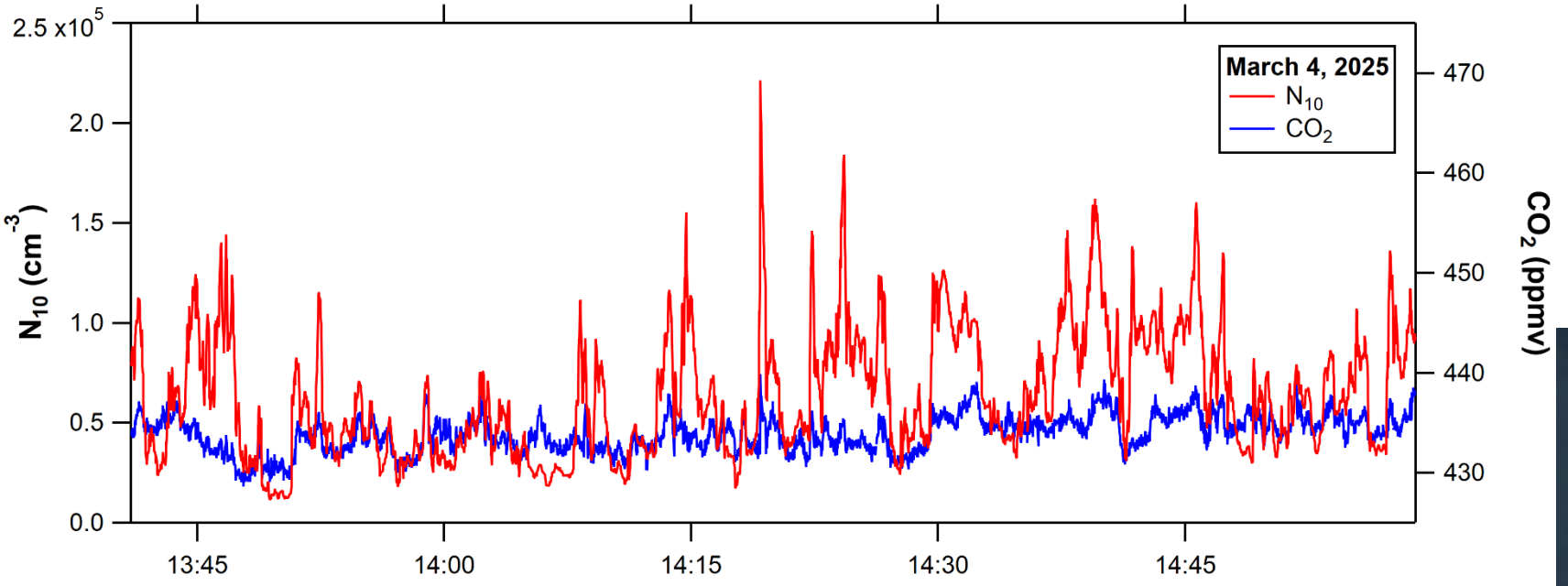
The top-down approach has been used for estimating the export flux of pollutants in continental outflow.

Survey measurements at Point A (March 10, 2022)





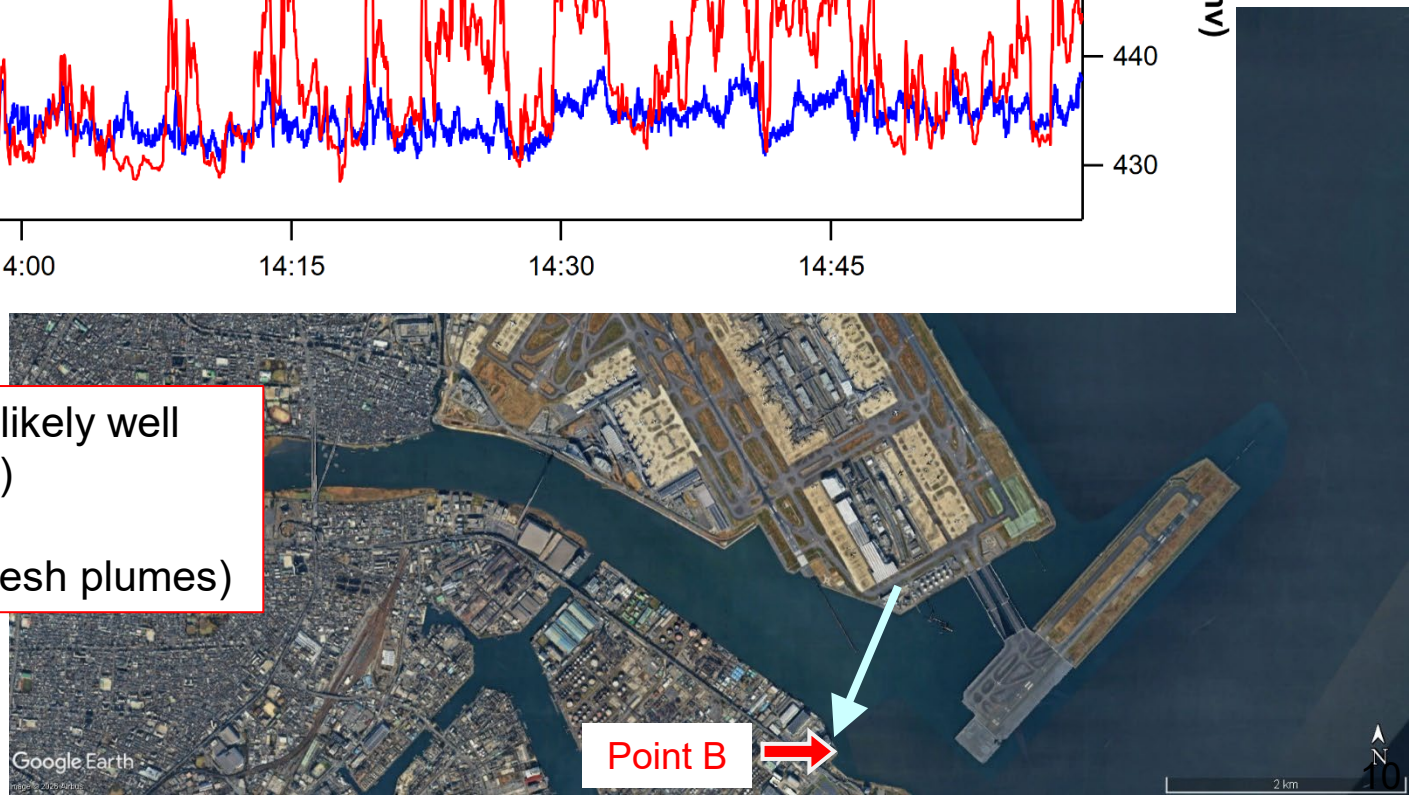
N_{10} and CO_2 measurements at Point B (March 4, 2025)



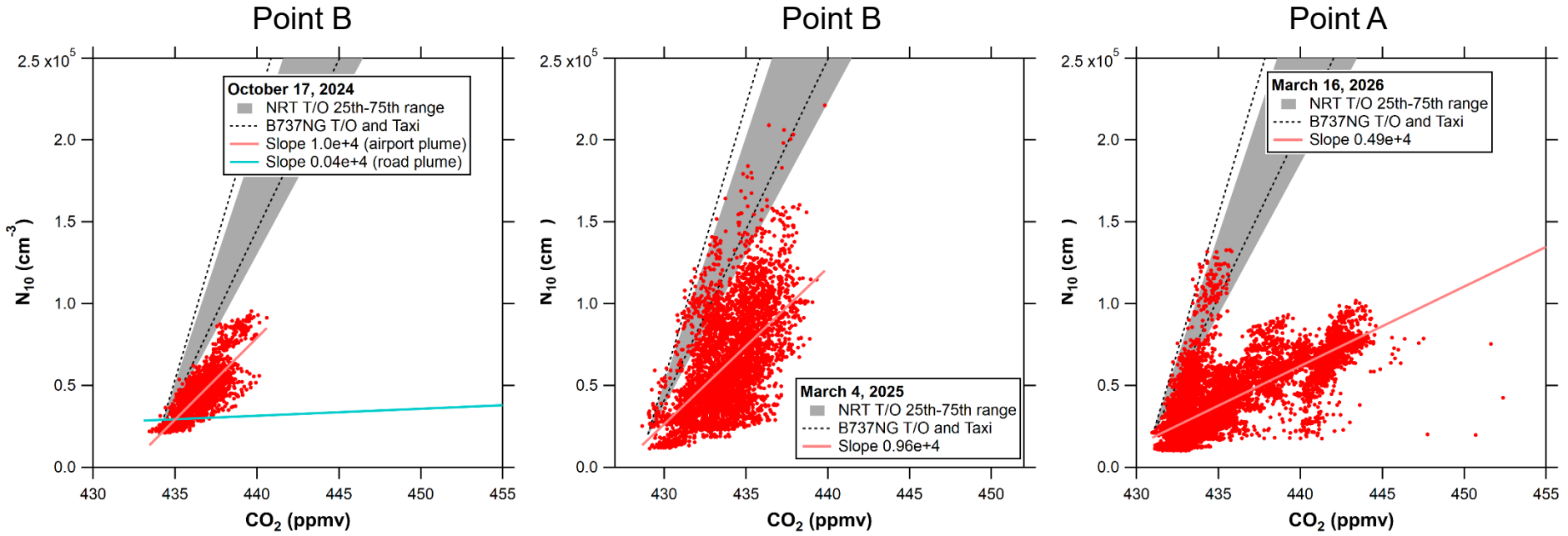
Baseline variations (likely well mixed in the domain)

+

Short-time spikes (fresh plumes)

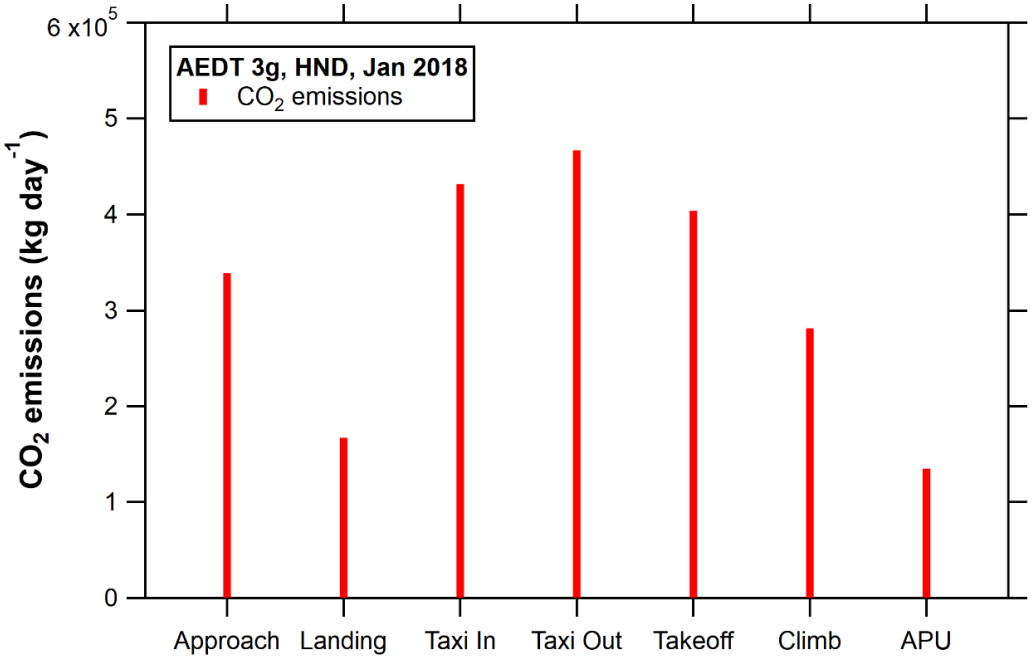


N_{10} and CO_2 correlations (3 days in 2024–2026)



- N_{10} is approximated as the UFP number concentration.
- Reference: takeoff plumes observed at Narita International Airport (NRT) (Takegawa et al., 2021); takeoff and taxiing plumes for B737NG (Moore et al., 2017; Takegawa et al., 2021; Takegawa, 2023).
- The $\Delta N_{10}/\Delta CO_2$ ratios for the short-time spikes agreed with the reference, whereas those for the baseline data were lower than the reference.
- The $\Delta N_{10}/\Delta CO_2$ ratios from HND were much higher than those for on-road plumes.

Particle number flux (Jan 2018 as a base case)



- The number flux of UFPs exported from HND is estimated to be:

  $(0.6–1.2) \times 10^{22}$ day^{-1} (= $(2–4) \times 10^{24}$ year^{-1})

  comparable to the particle emissions of ~10^{24} year^{-1} at Zurich airport (Zhang et al., 2020).

- Expanding the size range down to ~3 nm (UCPC) will greatly enhance the flux, but a tradeoff with rapid removal of small particles within the HND domain may be important.

Discussion

Remaining issues

- Variability and representativeness of the $\Delta N_{10}/\Delta CO_2$ ratios (uncertainty in the estimates).
- Comparison with other methods (e.g., ADS-B based estimates by Zhang et al., 2020).
- Contributions of sub-10 nm particles.
- Particle number flux of nonvolatile particles.
- GSE and APU emissions.

Conclusions and outlook

Conclusions

- The number flux of UFPs (~ N_{10}) exported from HND was estimated to be the order of 10^{22} day^{-1} by a top-down approach.
- Taxiing operations likely made large contributions.

Outlook

- Monitoring of N_{10} and CO_2 at selected sampling points in Tokyo to quantify the particle flux from HND and other sources (now planning).
- Expanding the size range (down to ~3 nm) and adding nonvolatile particle measurements.

References

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