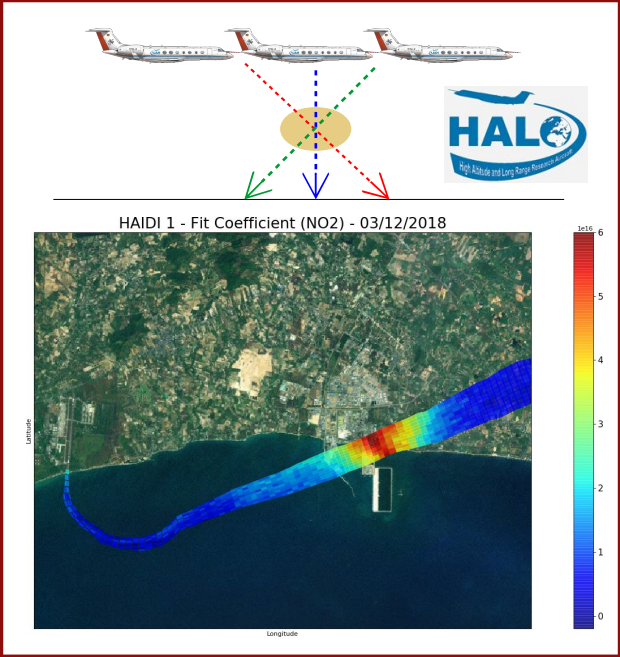

Aircraft-based 2- and 3D Trace Gas Measurements with HAIDI (Heidelberg Airborne Imaging DOAS Instrument) - Results of the EMeRGe Missions

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DFG - PL 193/21-1
SPP-1294 (HALO)

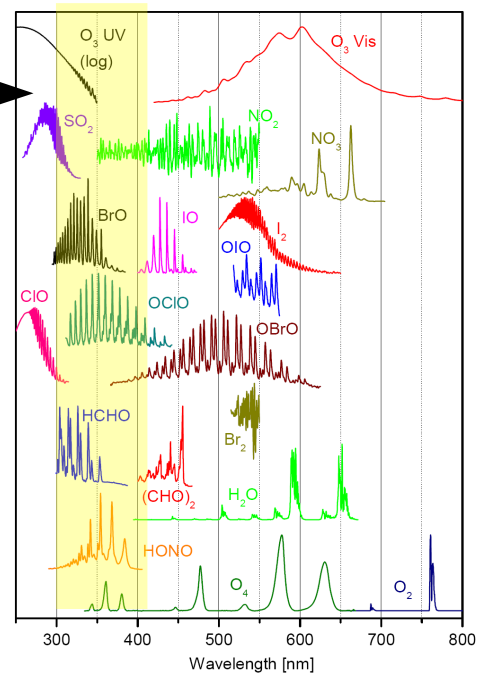
EGU 2020 // 04.-08. May 2020

AS3.23
EGU2020-1093

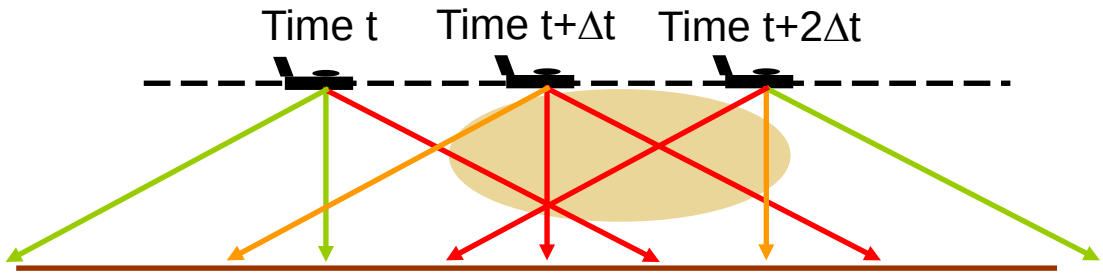
Heidelberg Airborne Imaging DOAS Instrument **(HAIDI)**

- **3x imaging DOAS spetrometers** obtain 2D trace gas slant column densities (SCD) and 3D trace gas distributions
- Objectives: image polluting trace gases, source attribution, derive emission rates

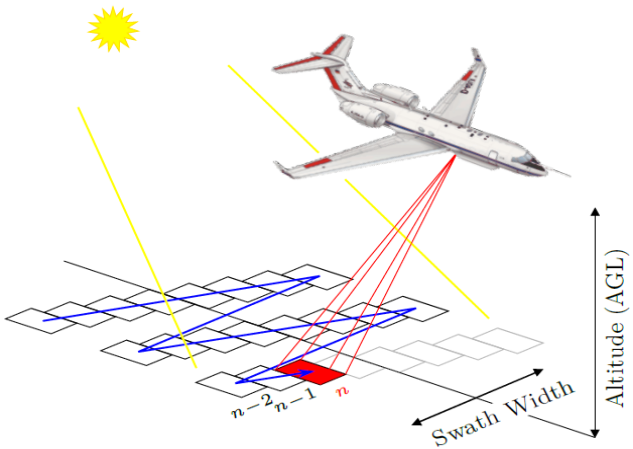
Measuring	**NO_2**, O_4, **HCHO**, HONO, **SO_2**, O_3, BrO, aerosol properties at 300 – 405 nm / ~0.5 nm resolution
Spatial coverage	40 x 40 m, swath width ~1500 m at 1500 m altitude 266 m x 266 m, swath width ~10 km at 10 km altitude
Temporal coverage	up to 10 ms / spectrum



Heidelberg Airborne Imaging DOAS Instrument (HAIDI)



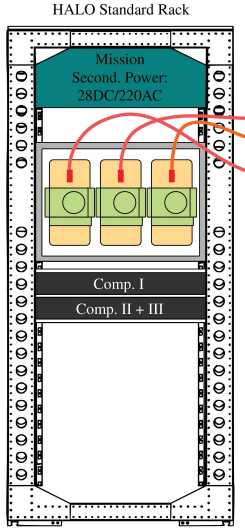
The three separate viewing angles (nadir, 45° forward and 45° backwards) allow a reconstruction of the vertical trace gas distribution.
The absorber is first seen in the forward-viewing telescope, then appears in the nadir and finally in the backwards-viewing telescope.

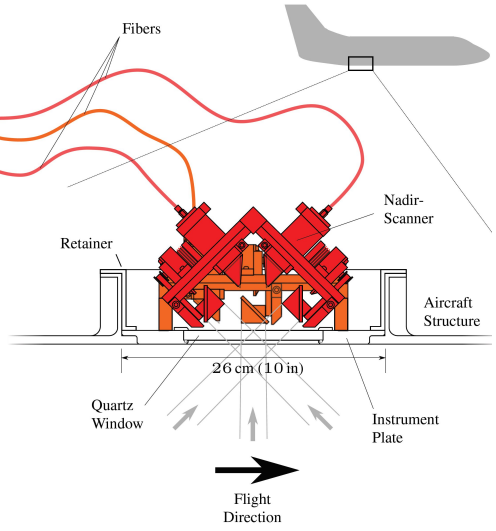


General et al (2014)

Each telescope scans orthogonally to the flight direction to offer horizontal imaging. The swath width is set to approximatly equal the flight altitude.

The system consists of a standard HALO rack component with a computer control box and three separate spectrometers connected to the telescopes via glass fibres.





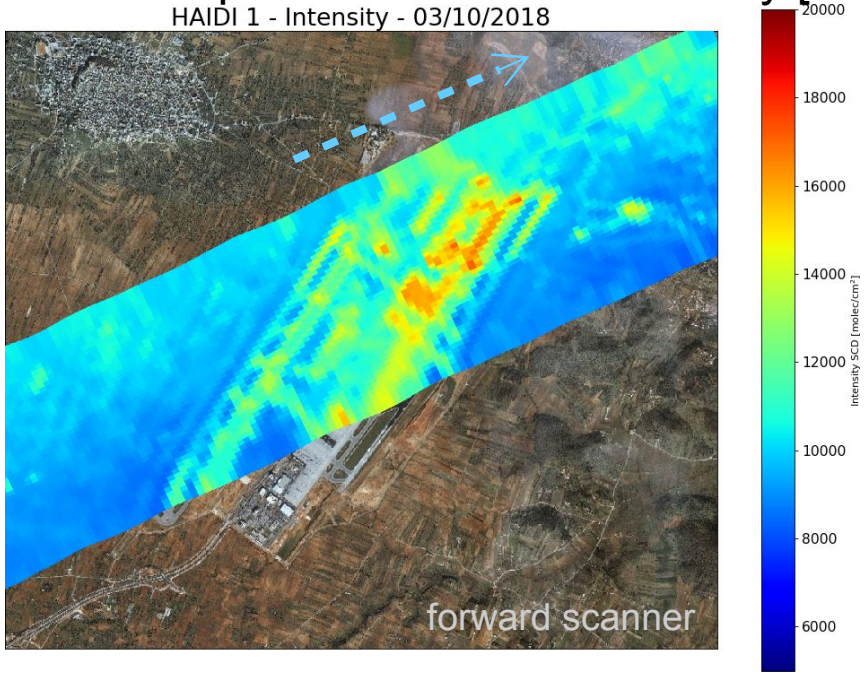
General et al (2014)

HAIDI Spatial Resolution

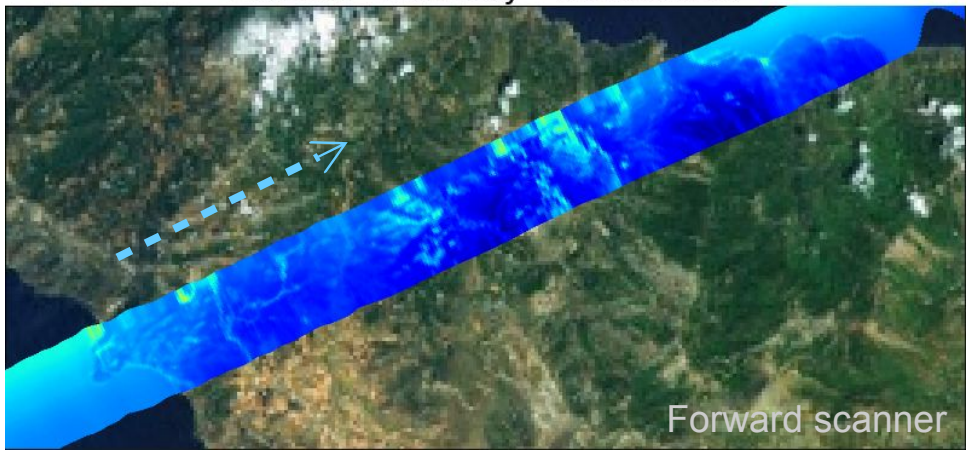
The high light throughput of the systems allow a very high time and thus spatial resolution even on-board a fast-flying jet airplane such as HALO.

This airport close to Athens (Greece) appears clearly in the intensity of the HAIDI pixels.
The terrain including large streets, mountains and the coast are also easily visible.

Airport near Athens Intensity [a.u.]



Terrain in Greece



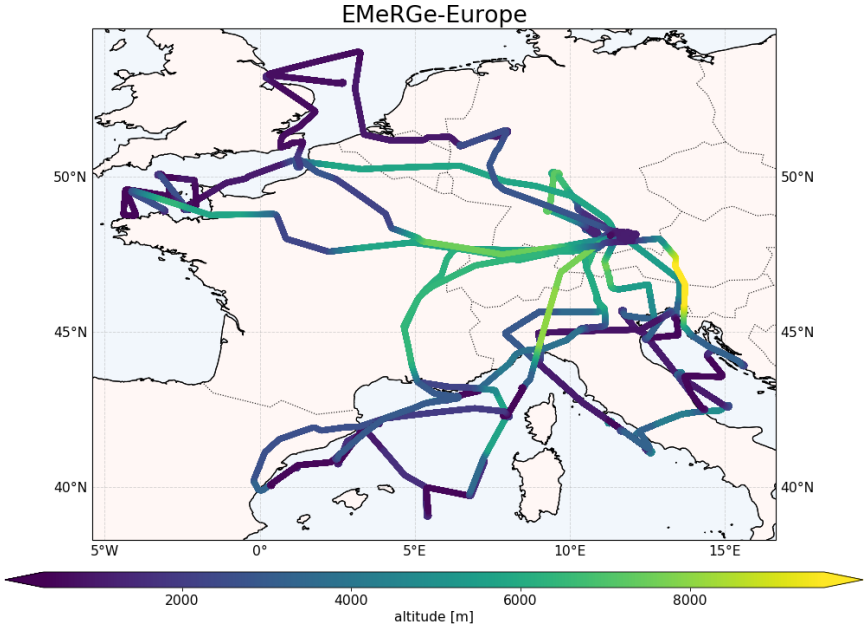
The EMeRGe campaign

"Effect of Megacities on the Transport and Transformation of Pollutants on the Regional to Global Scales"

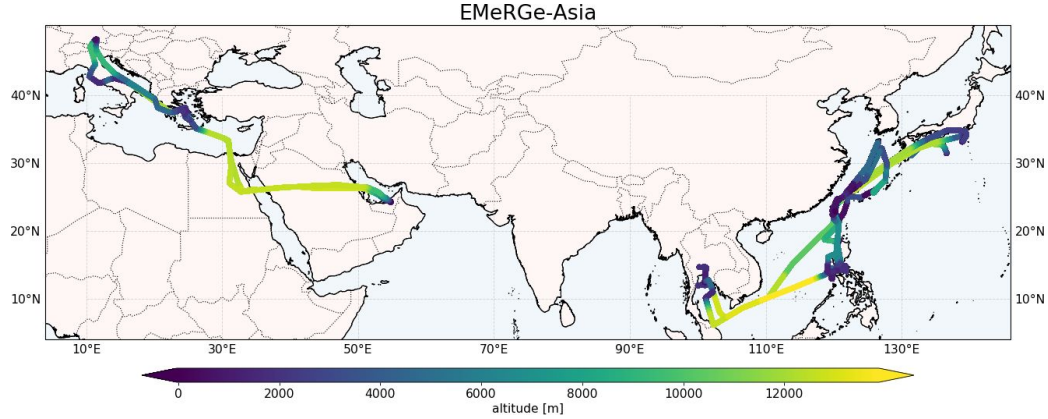
More information:

www.iup.uni-bremen.de/emerge

+ other contributions of this session

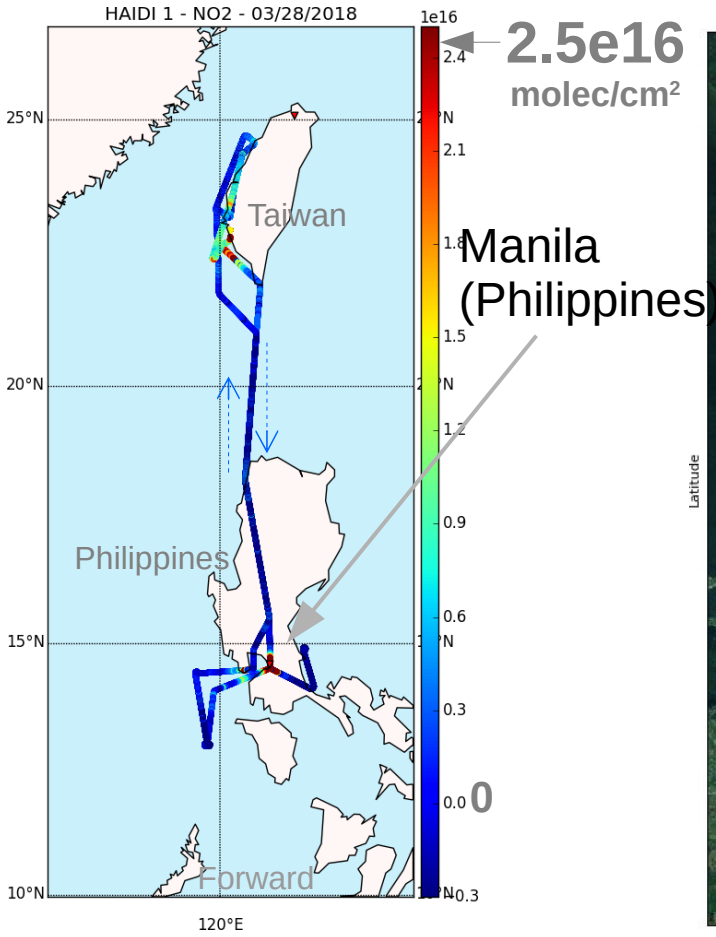


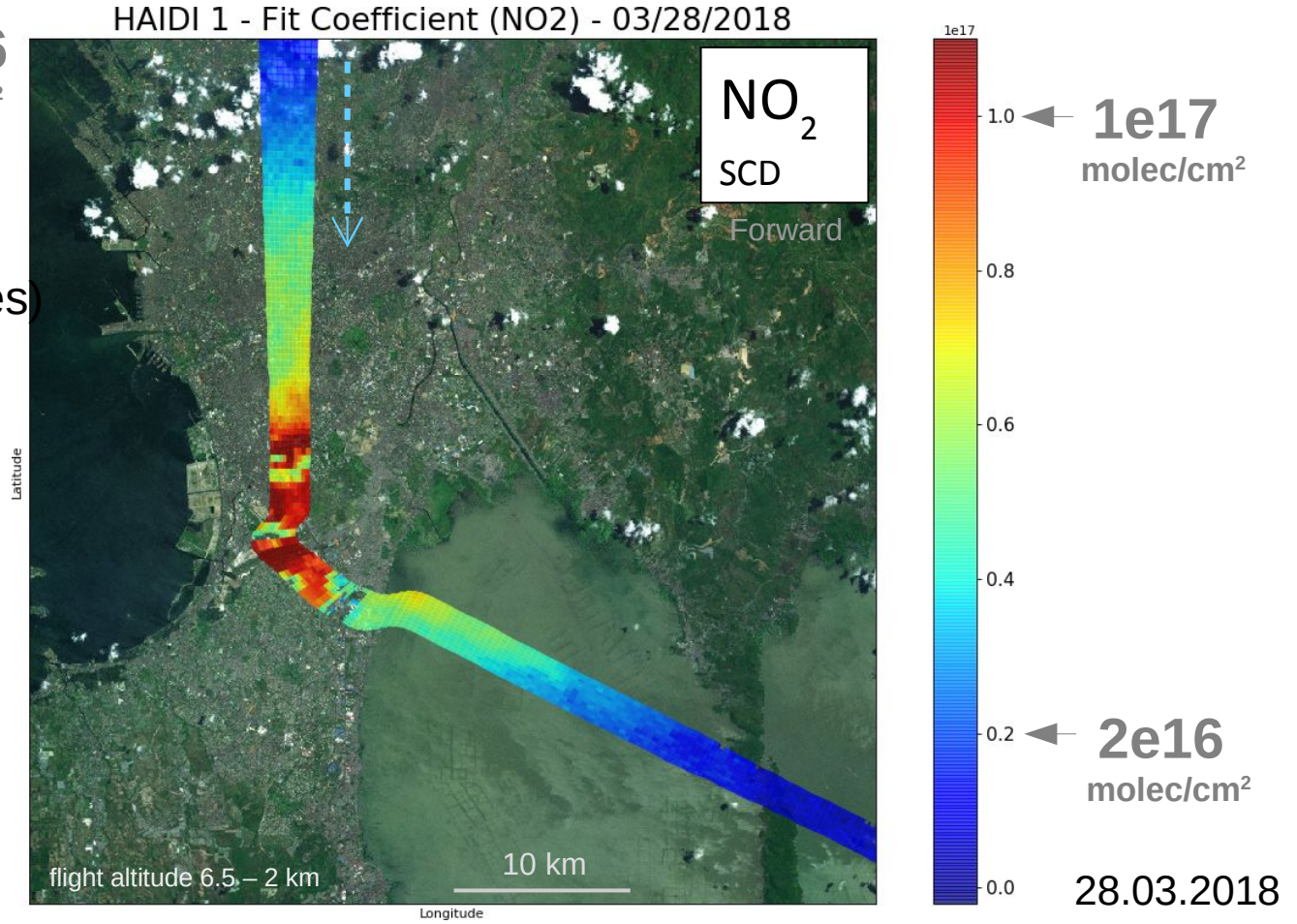
July 2017
based in Oberpfaffenhofen / Germany
9 mission flights
55.37 million spectra collected by HAIDI



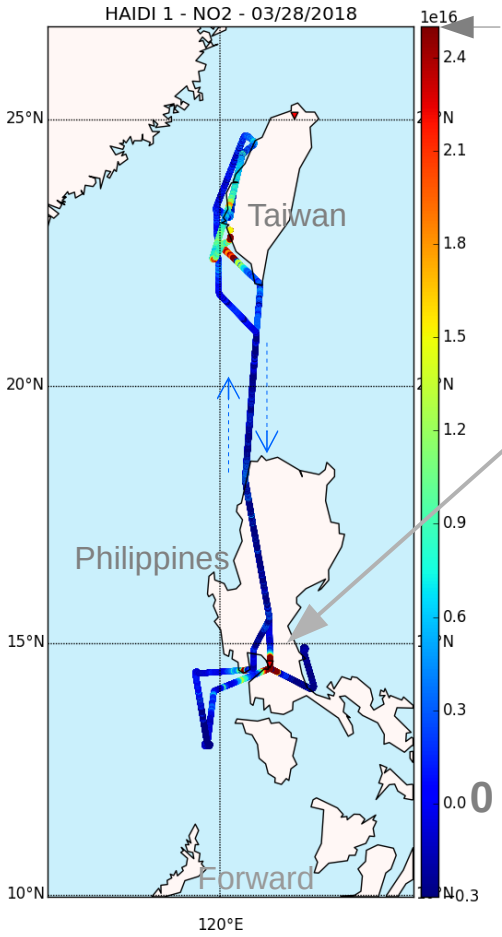
March/April 2018
based in Tainan / Taiwan
14 mission flights (including 4 transfer flights)
116.41 million spectra collected by HAIDI

NO_2 Distribution – Manila/Philippines (#10 2018/03/28)

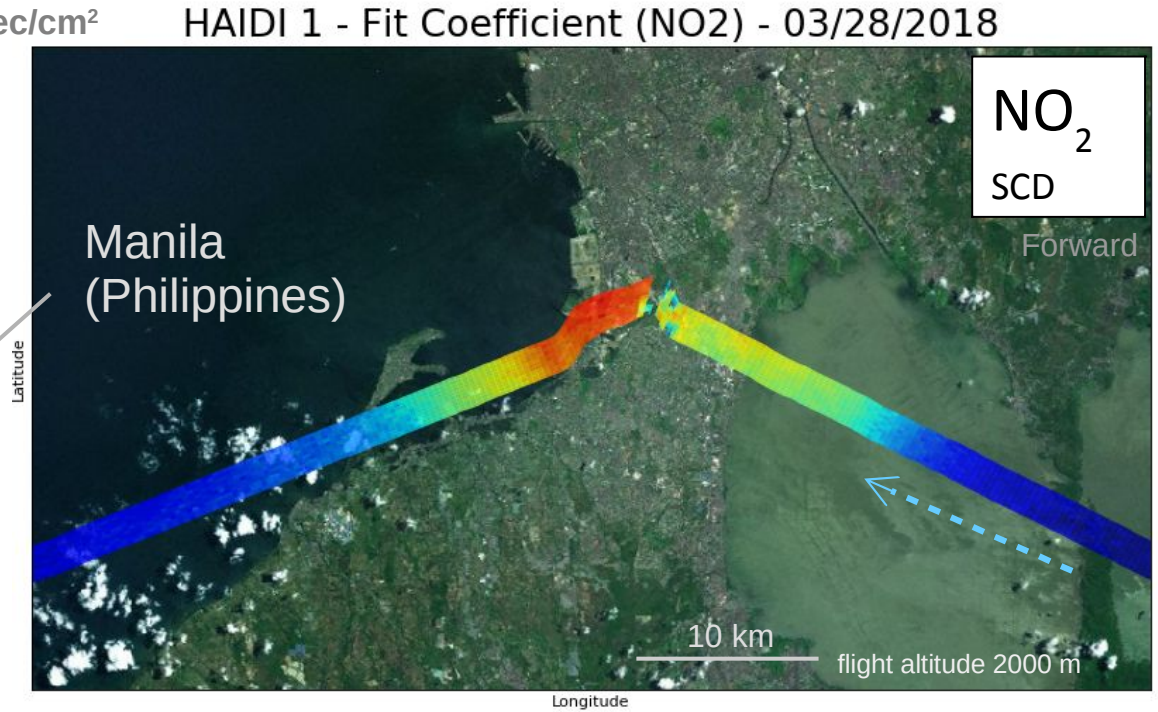


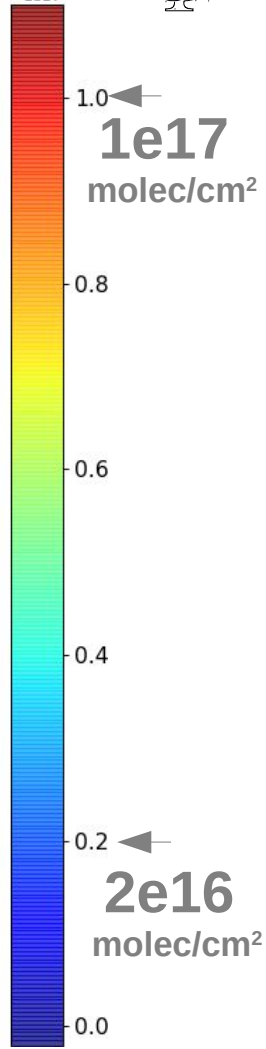


NO_2 Distribution – Manila/Philippines (#10 2018/03/28)



2.5e16 molec/cm²





1e17 molec/cm²

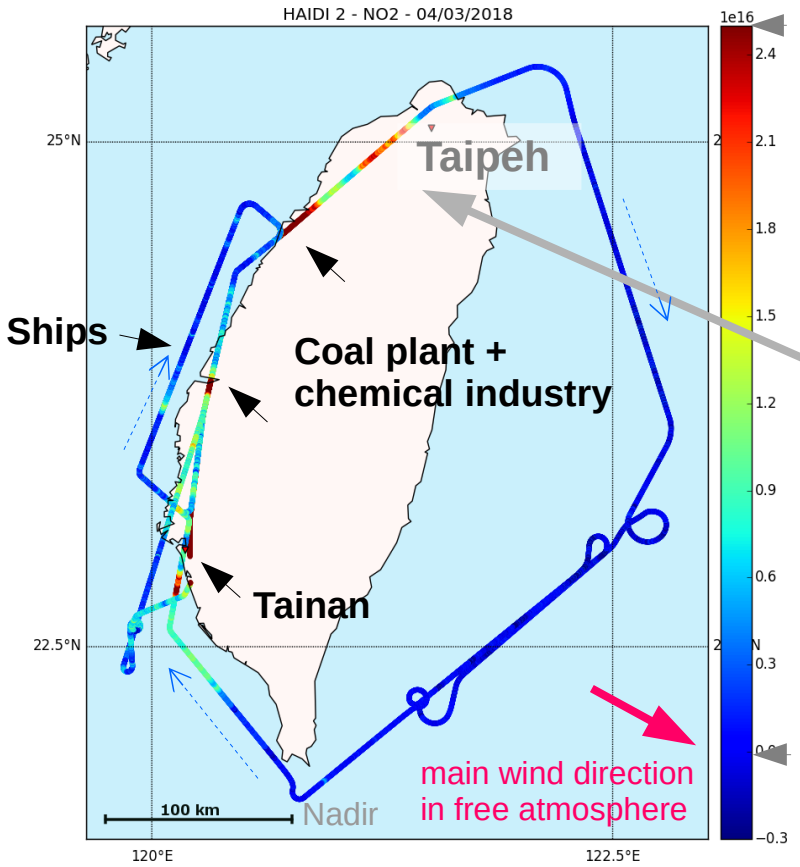
2e16 molec/cm²

→ very high NO_2 concentration over city

→ no small-scale structure visible

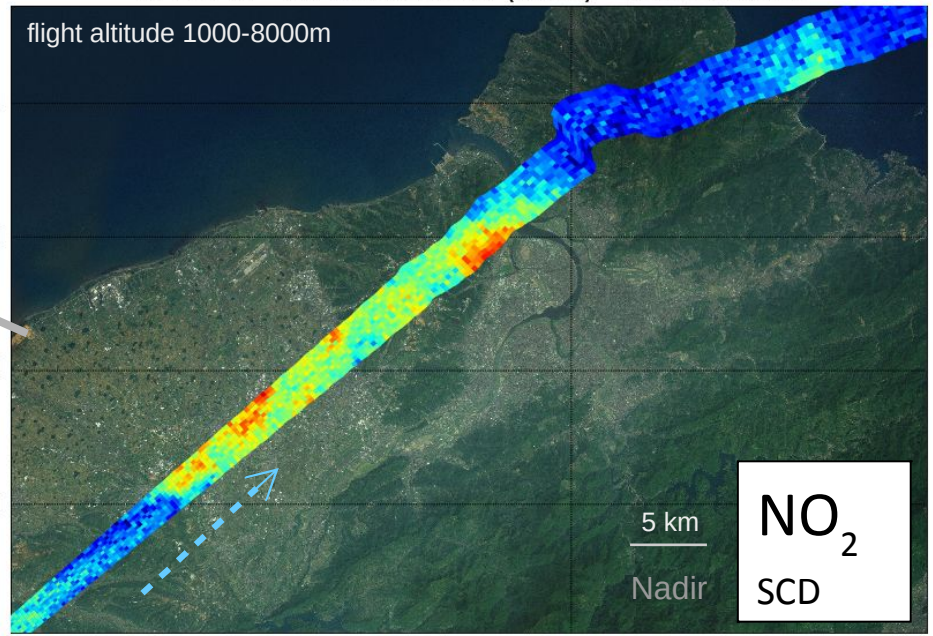
28.03.2018

NO_2 Distribution – Taipei (Flight 12 – 2018/04/03)



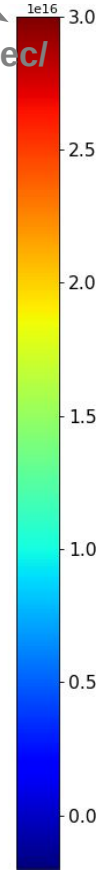
2.5e16 molec/cm²

0 molec/cm²



3e16 molec/cm²

0

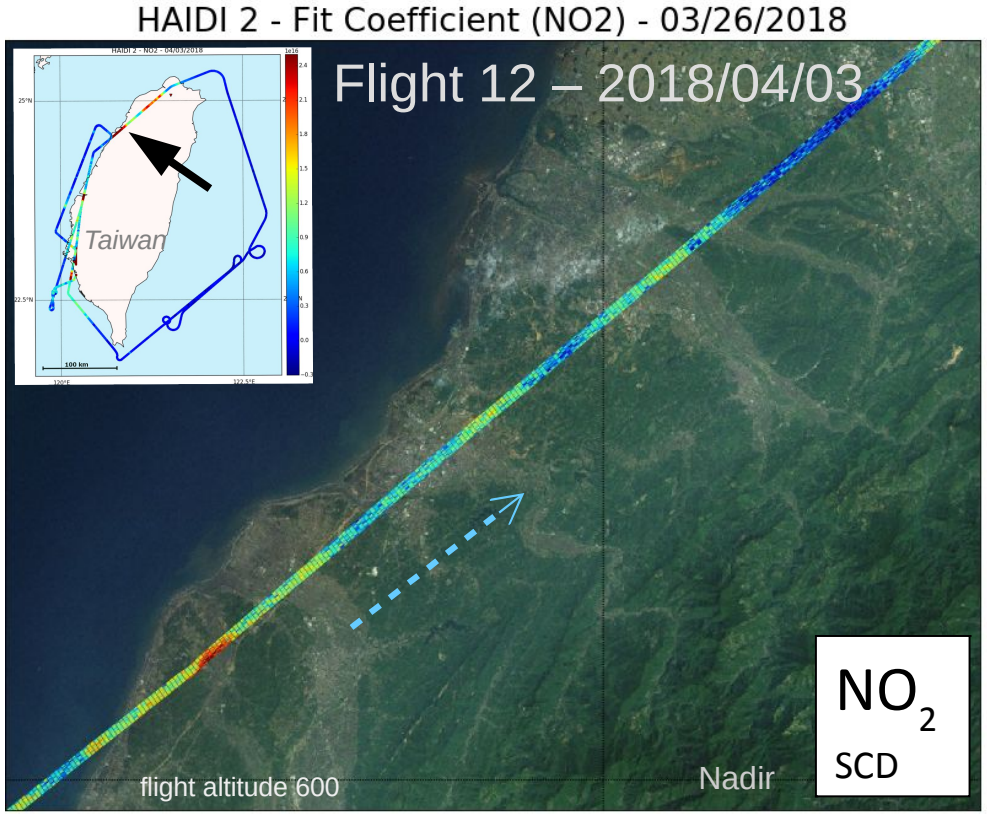


→ small-scale NO_2 variability

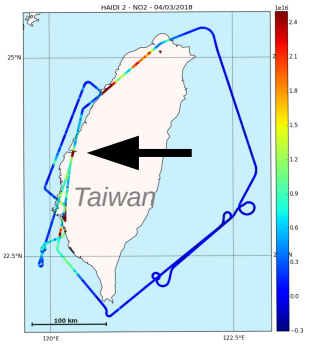
→ heterogeneously distributed local sources

NO_2 Distribution – Taipeh/West Coast - Conclusions

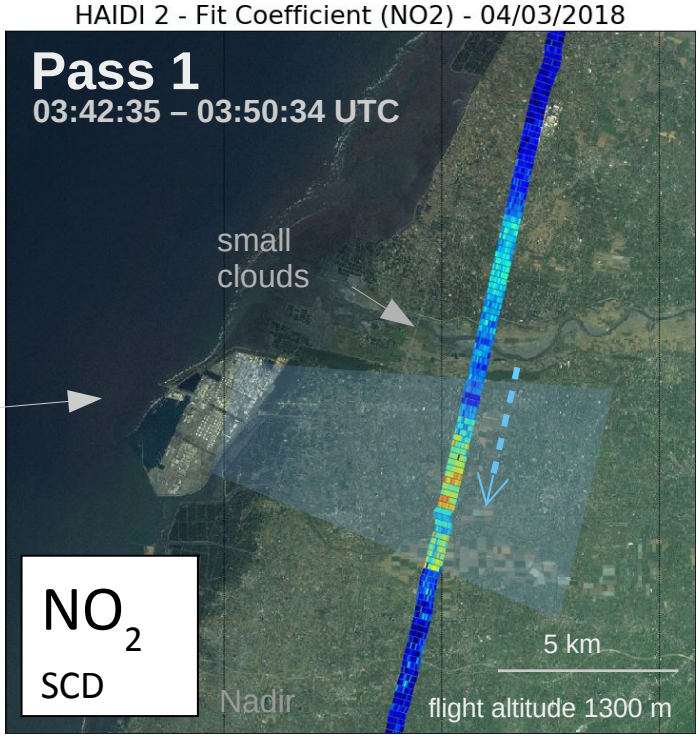
- small-scale NO_2 variability along the whole west coast
- Occasional localized very high NO_2 columns with changing position
- →smaller distributed sources, but also a small number of bigger sources

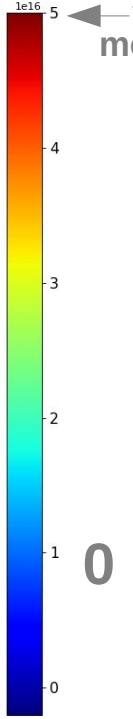


Power Plant Plume I (Flight 12 – 2018/04/03)

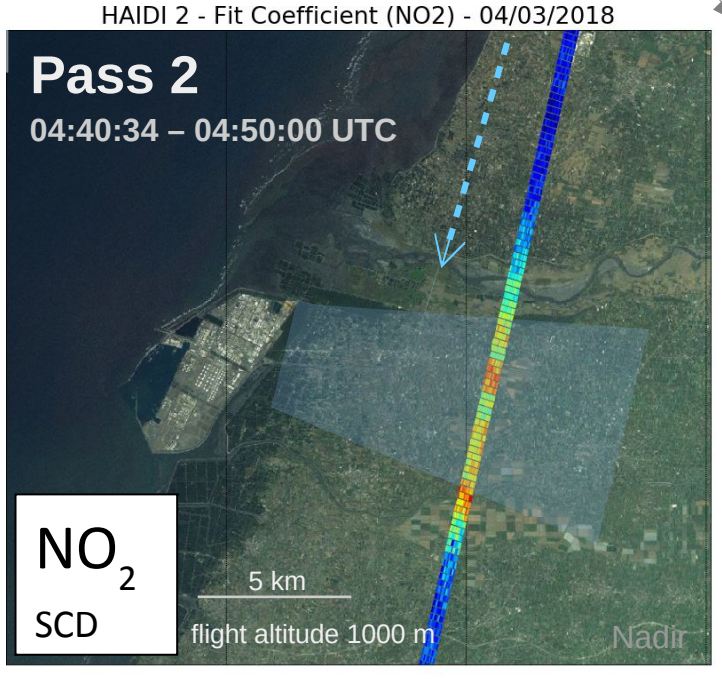


Formosa Chemicals & Fiber Corp / Mailiao Power Plant (coal, 4,200 MW)
麥寮台塑 工業園區

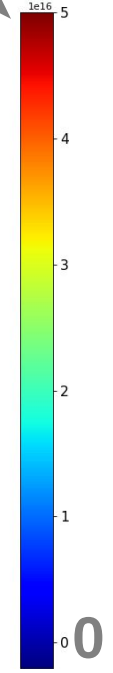




5e16 molec/cm²



5e16 molec/cm²



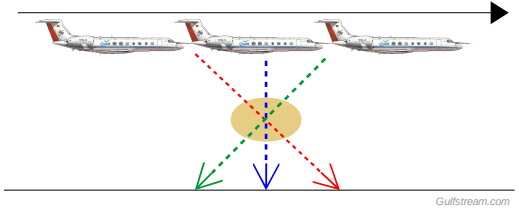
→ clear NO_2 plume visible on several overflights

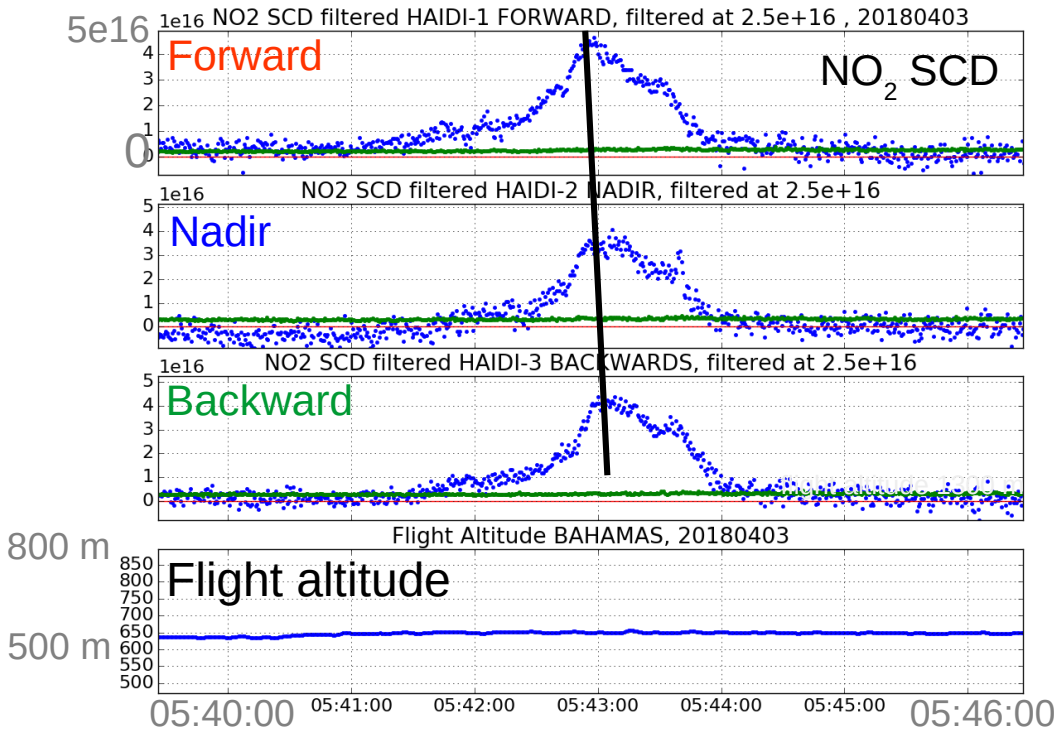
https://en.wikipedia.org/wiki/Mailiao_Power_Plant

Power Plant Plume I (Flight 12 – 2018/04/03)

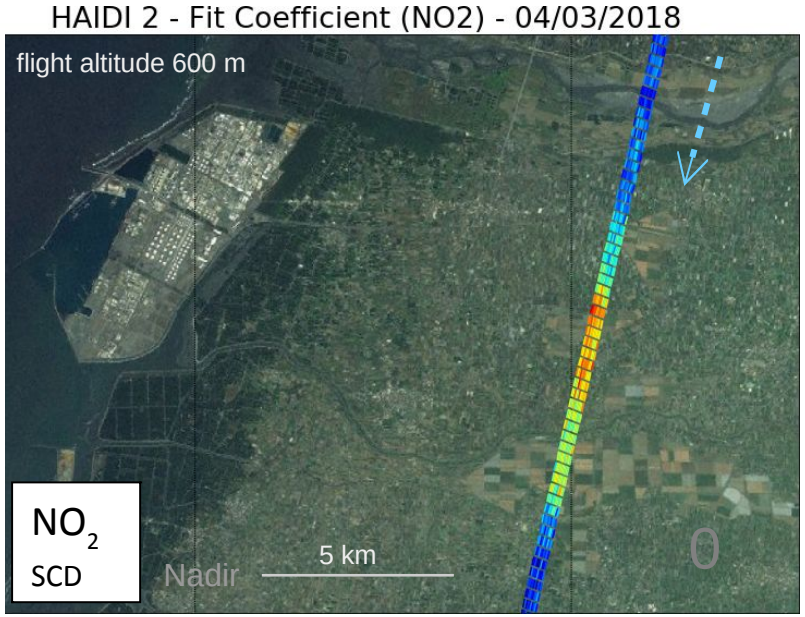
Pass 3

05:40:34 – 05:45:34 UTC



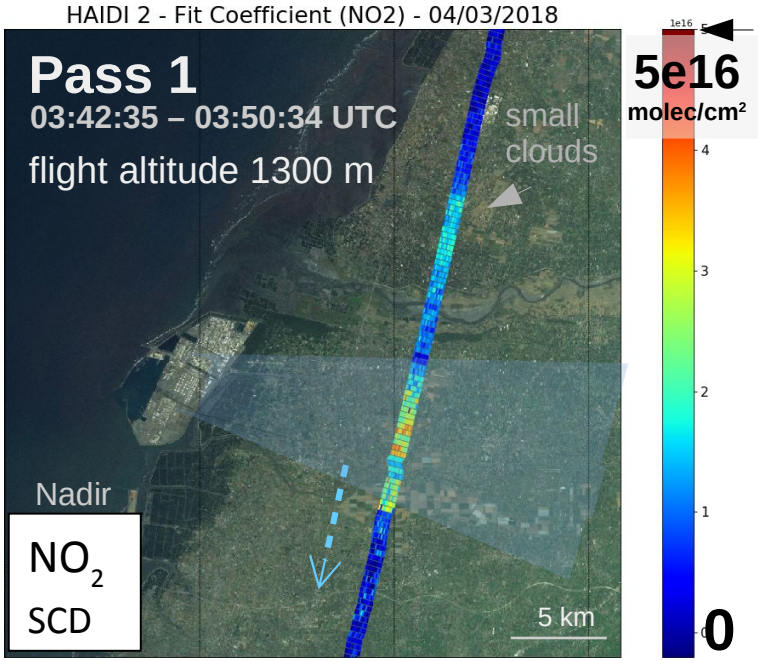


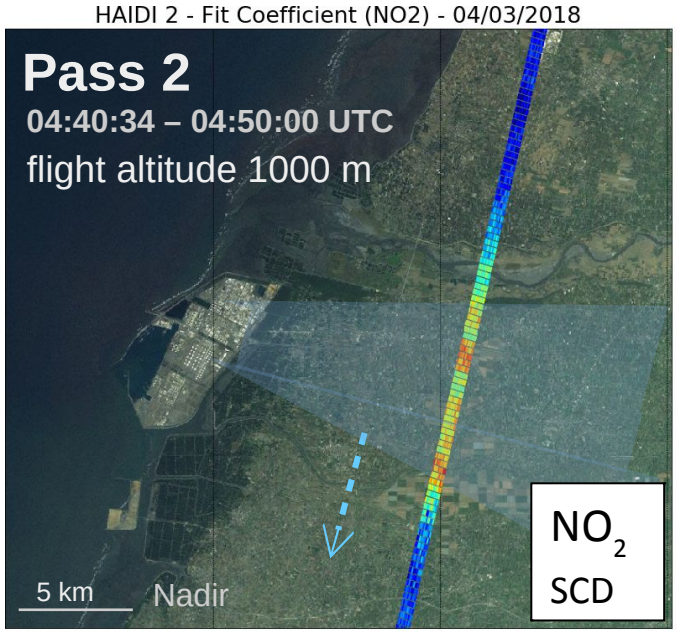
3.5e16
molec/cm²

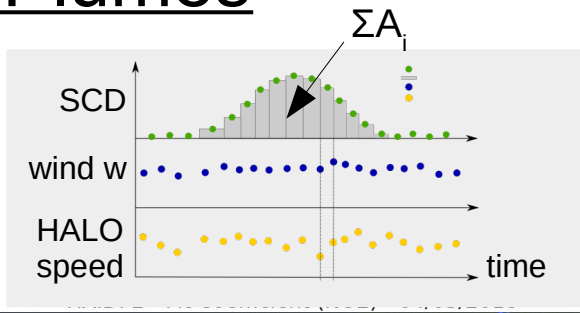


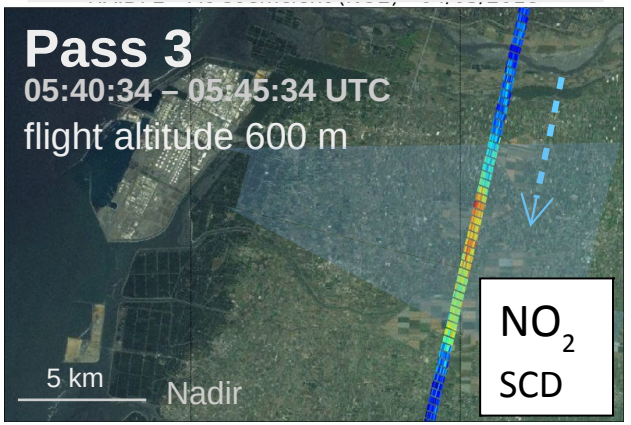
→ plume height from triangulation: ~300m

Emission Estimation of Power Plant Plumes







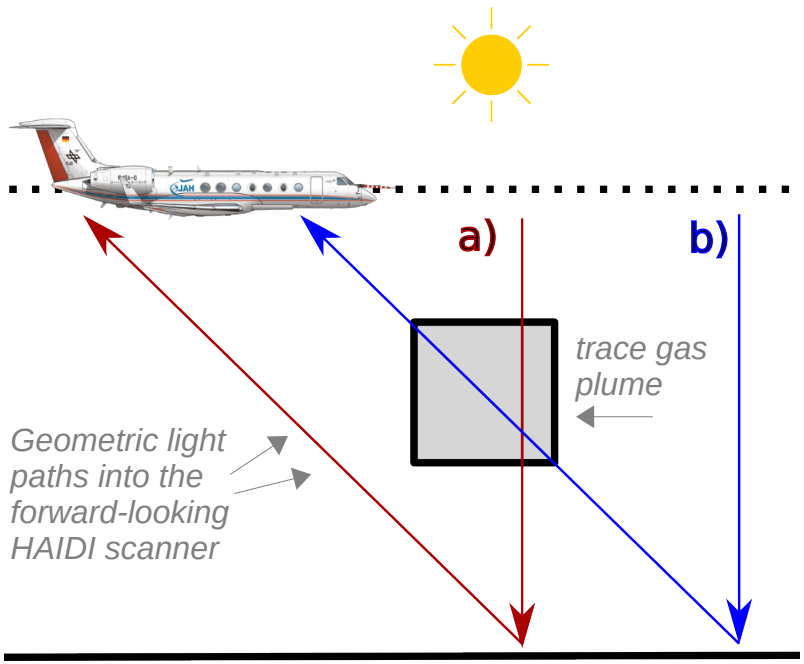


ΣA_i = 133 g/m	ΣA_i = 161 g/m	ΣA_i = 105 g/m
I* = 115 t/day	I* = 139 t/day	I* = 91 t/day

with wind of 10 m/s (estimated by Taiwanese partners)

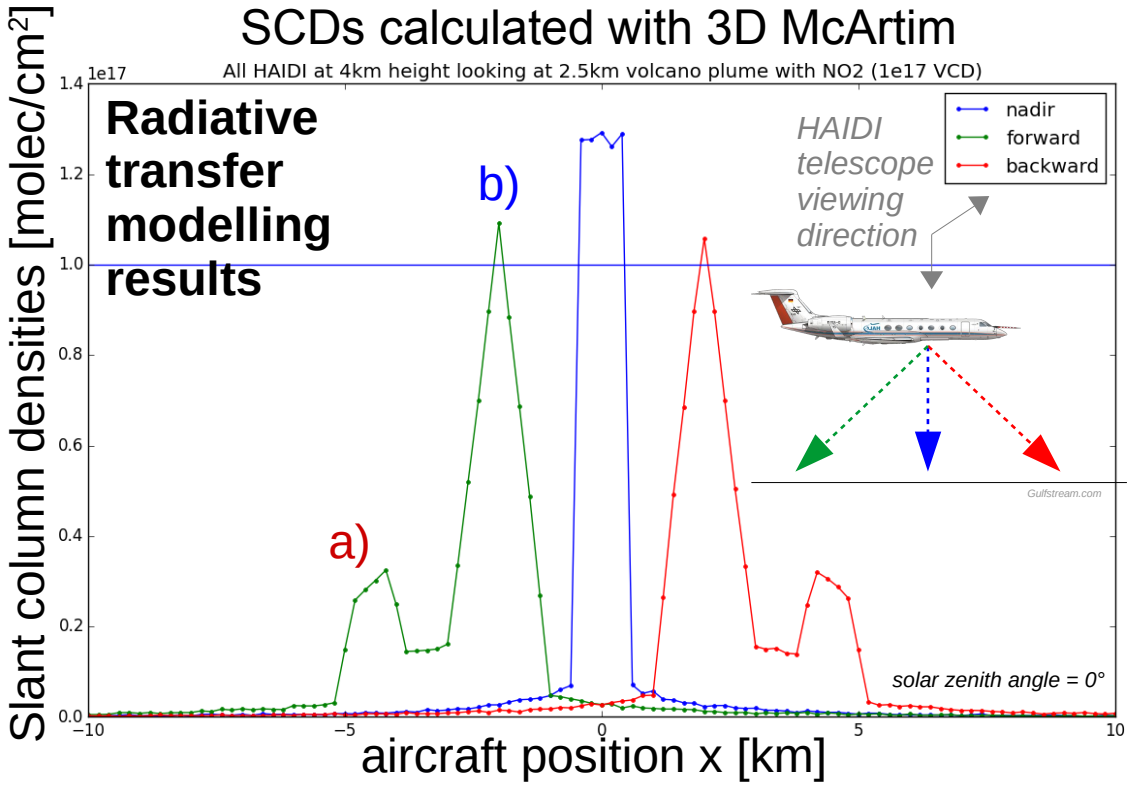
(Assuming an air mass factor of 2)

Observing Trace Gas Plumes in 3D



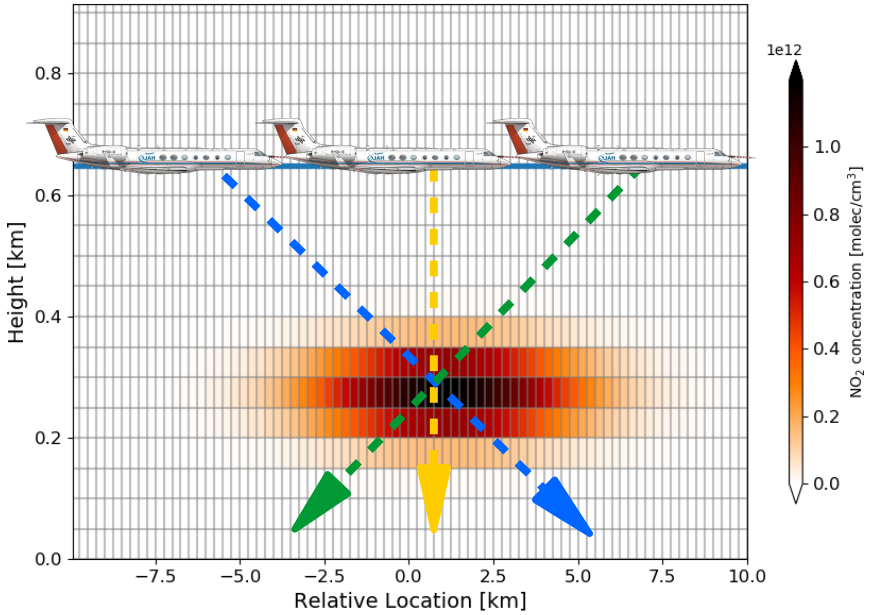
→ A localized plume of trace gas can be seen twice by HAIDI.
→ Depending on sun position, this can be at different locations (eg **a** or **b**).

→ Also, the three scanners see the plume at different aircraft locations.



→ Together, this contains information about the vertical distribution of the gas.
→ We use the radiative transfer model McArtim for inversion.

Observing Trace Gas Plumes in 3D – Basic Version



Information from the Real World

→ NO_2 slant column densities (by HAIDI)
→ sun position
→ airplane altitude and location
→ ground albedo

Approach & Assumptions

→ radiative transfer modelling of box airmass factors with McArtim in 3D mode

→ assuming a plume with Gaussian crosssection perpendicular to flight track

→ 4 free parameters for the Gaussian shape (x, z, sigma_x and sigma_z) & 1 free parameter for the maximum column

→ Derive these parameters from fitting the slant column densities calculated from the model to the measured values

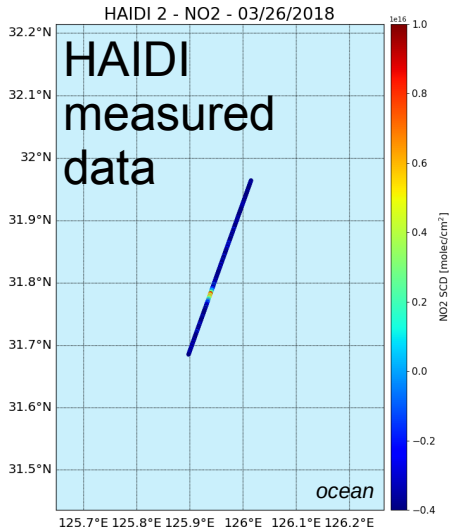
Inversion of a small ship plume

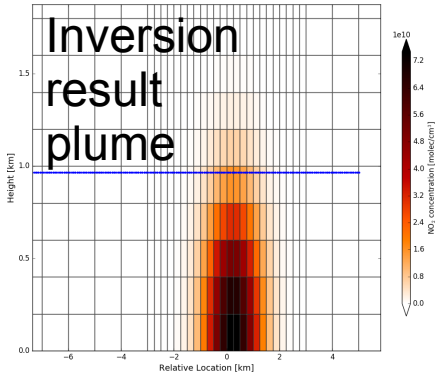
Asia-09
26.03.2018
–
04:42:00 – 04:44:00

First results show:

→ The Gauss simplification works.

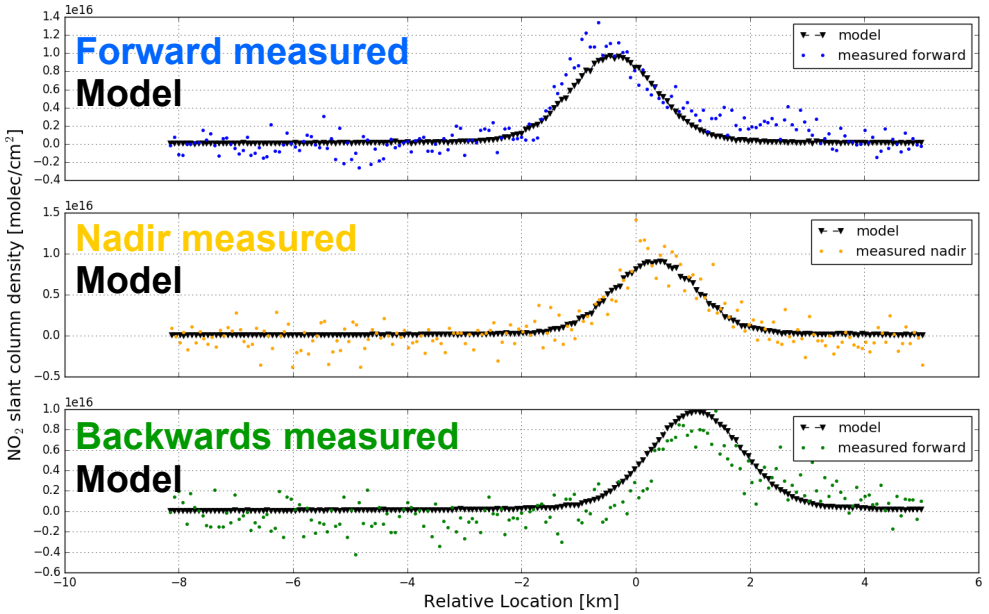
→ Errors in plume height and vertical diameter are still large.





First Inversion results

horizontal plume diameter	1.4 +/- 0.1 km
maximum vertical NO_2 column	5.00e+15 +/- 1.17e+15 molec/cm²
plume height	0 +/- 1.298482 km
vertical plume diameter	0.9 +/- 1.9 km



Summary

The Heidelberg Airborne Imaging DOAS Instrument (HAIDI) measured high resolution 2D/3D trace gas distributions (NO_2, SO_2, HCHO) during EMeRGe campaign (megacities) in Asia and Europe.

→ Horizontally resolved NO_2 distribution in cities
- relatively homogeneous in Manila, more diverse in Tainan

→ Located and analysed plumes of power stations, industry and ships (height, emission rates)

→ Radiative transfer calculations can be used to estimate the 3D distribution of these plumes