Transport and chemical conversion of air pollutants under convective conditions – Results of the COPS-TRACKS campaign

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Introduction:

In July 2007, the COPS-TRACKS campaign (Transport and Chemical Conversion in Convective Systems) was carried out in southwestern Germany in order to study the transport of atmospheric trace gases and aerosols under convective conditions. During TRACKS, the dillution of air pollutants around Karlsruhe, a city with moderate anthropogenic emissions, has been detected by coordinated measurements of ground based stations and different airborne platforms. We show results of measurements by the *DO 128* (TU Braunschweig/IMK Karlsruhe), completed by a model simulation of COSMO-ART.

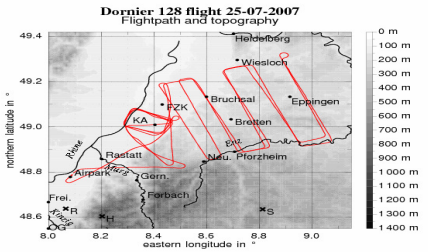

Fig.1: Orography and two-dimensional view on the flight pattern of the DO 128 (*'KA' = Karlsruhe*; *'FZK' = Forschungszentrum Karlsruhe, now KIT).*

Measurement performance:

- *Day of investigation:* July 25, 2007
- *Weather conditions:* high pressure situation with 1/8 cloudiness and a maximum temperature of about 24°C. Wind from westerly directions between 3 ms^{-1} and 8 ms^{-1}.
- In the lee of Karlsruhe, three aircraft and a zeppelin flew between 13:20 UTC and 17:40 UTC inside the convective boundary layer.
- The anthropogenic emissions of air pollutants mainly result from traffic and industry.

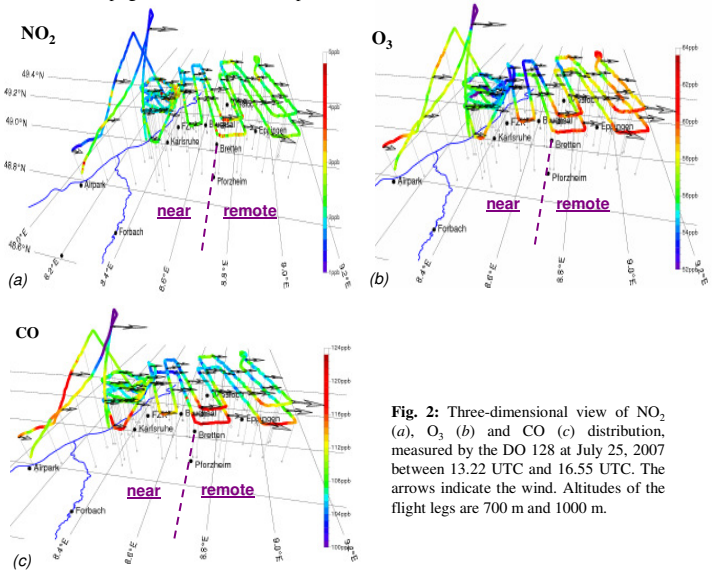

Fig. 2: Three-dimensional view of NO_2 (*a*), O_3 (*b*) and CO (*c*) distribution, measured by the DO 128 at July 25, 2007 between 13.22 UTC and 16.55 UTC. The arrows indicate the wind. Altitudes of the flight legs are 700 m and 1000 m.

Measurement results:

- No explicit plume in the lee of Karlsruhe detectable (Fig. 2a).
- Moderate O_3-concentrations above and in the near lee of Karlsruhe (Fig.2b): ≈ 53 ppb.
- Enhancing of O_3 with increasing distance to Karlsruhe (Fig.2b): ≈ 61 ppb.
- Gradient of the O_3-distribution in north-south direction with higher concentrations up to 63 ppb at the borders and lower concentrations inside the mattress-like pattern.
- Moderate concentrations of CO; in principle the same distribution pattern as O_3: lower values inside the mattress-like pattern (≈ 106 ppb), higher values at the leg borders (≈ 122 ppb) (Fig.2c).

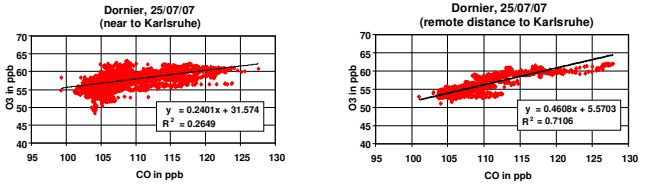

Fig. 3: Correlation of O_3 and CO in the near and in the remote lee area of Karlsruhe.

The correlation of O_3 and CO is splitted for the near and the remote lee area (Fig. 3), the borderline is set to **20 km** away from the city emission sources (Fig. 2).

- **Near lee area:** determination coefficient $R^2 = 0.26$, O_3/CO-correlation is unsignificant.
- **Remote lee area:** determination coefficient $R^2 = 0.71$, O_3/CO-correlation is significant positive. $\Delta O_3/\Delta CO = 0.46$.

The regional model COSMO-ART:

- Horizontal resolution: 2.8 km. Start of simulation at 24/07/07, 0:00 UTC.
- Nested run: start with COSMO-ART in 14 km coarse grid resolution.
- Initial and boundary conditions for the coarse grid run were provided by GME (meteorology) and MOZART (chemistry).
- COSMO-ART shows relative high NO_2-values in north-east of France, reaching also the environment of Karlsruhe (Fig. 4).
- Positive correlation of O_3 and CO in the remote lee area: $R^2 = 0.4$, $\Delta O_3/\Delta CO = 0.05$ (Fig.5).

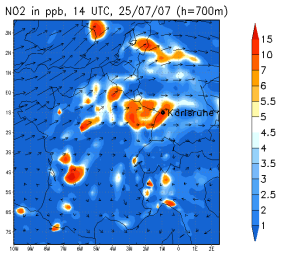

Fig. 4: COSMO-ART, coarse grid run (horizontal resolution = 14 km): NO_2 at 14 UTC in the altitude of 700 m. The axis labels indicate rotated coordinates.

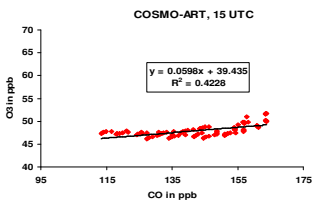

Fig. 5: COSMO-ART (horizontal resolution = 2.8 km): correlation of O_3 and CO in the remote lee area of Karlsruhe. Chosen grid points correspond to the measurement area and altitude .

Comparison of COSMO-ART and measurement data:

- Modelled O_3 concentrations are in the same magnitude as measured. However, eastward of Karlsruhe a tongue-shaped area shows O_3 concentrations ≈ 7 ppb lower than measured (Fig.7). Therefore, the O3/CO-correlation of COSMO-ART is less distinctive than in the measurements.
- Modelled CO concentrations are higher than measured with an offset by about 35 ppb.
- Ozone precursors like NO_2 and CO are transported from France into the lee area of Karlsruhe (Fig. 4 and 7).

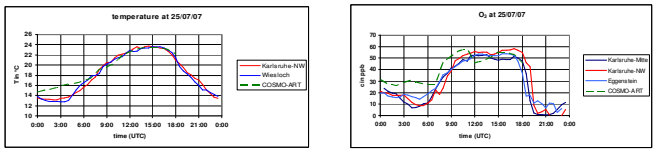

Fig. 6: COSMO-ART results compared to ground based measurements (by LUBW).

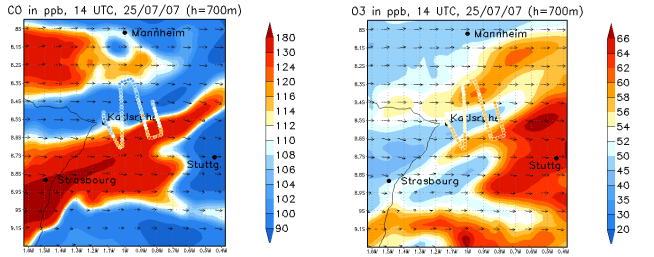

Fig. 7: COSMO-ART results (horizontal resolution: 2.8 km) inside the convective boundary layer compared to airborne measurements (coloured circles) for CO *(left)* and ozone *(right)*. An offset of 35 ppb has been substracted from CO data of COSMO-ART. The axis labels indicate rotated coordinates.

Summary - a case study:

- Moderate convective summer day → no significant city plume of Karlsruhe identifiable.
- In the ***near lee area*** of Karlsruhe no significant correlation between O_3 and CO → local emission sources determine the chemical conversion processes.
- In the ***remote lee area*** (distance to Karlsruhe > 20 km) a significant positive correlation between O_3 and CO → long-distance transport of ozone precursors predominates local emission sources.
- Transport of NO_2 and CO enriched air masses from northeast of France to Karlsruhe.
- In complex terrain (Upper Rhine Valley), the predominance of either local chemical conversion or transport processes can even change at short distances inside the convective boundary layer .
- COSMO-ART is able to reproduce fine structures in gas distributions, but partly with slight temporal or local displacements (ozone).
- **COSMO-ART combines information of the regional scale with highly resolved local effects → important tool for understanding measured trace gas distributions in complex terrain.**

References:

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