TROPOSPHERIC EXPLORATION ABOVE MOLDAVIA PROVINCE:
TRACE GAS MEASUREMENTS
ATR-42 FLIGHT AS0729 ON THE 16TH OF JULY 2007

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Résumé: L'exploitation troposphérique au-dessus de la Provence Moldova: le vol 
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The chemistry flight as0729 performed on the 16th of July 2007, between 
14h20 and 16h20 local time was dedicated to pollution tracking above the Moldavia 
province in Romania. We wanted to explore two urban agglomerations: Iasi 
(47°09′N; 27°37′E) and Roman (46°55′N; 26°54′E) distant about 50 km from one 
another in straight line. Industrial zones are implanted in these areas. We went to 
explore the vertical distribution of the pollutants above these two areas. Moreover, a 
European road passes by the north of the two cities. We also went to track traffic 
emissions. Trace gas species measured during the flight were NOx, O3 and CO. Our 
goal is to establish the lower troposphere distribution of these pollutants in the area, 
in order to evaluate the photochemical production of ozone in an urban/industrial 
plume. The aim of our experimental strategy is to cover a horizontal and vertical 
dimension of the region.

1. FLIGHT PREPARATION

To prepare the flight, we localized the urban pollution emission points such 
as industrial zones (pharmaceutical factory, metallurgy plant) and important traffic 
axes (European Road E85 and E583).

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From a meteorological point of view, the forecasting announced favorable conditions for photochemical ozone production:
- High temperature up to 35°C \(\Rightarrow\) important photochemistry;
- Anticyclone conditions \(\Rightarrow\) stability;
- Low wind from the North West at 3 m/s.

According to these conditions we established our flight plan to collect the air masses downwind the sources areas.

2. FLIGHT DESCRIPTION AND TRAJECTORY

Our flight strategy consisted in performing a vertical exploration of three domains: two urban zones and one remote atmosphere above a forest separating the two cities. To do so, we did 3 vertical profiles between 2500’ and FL180. Besides, to carry out a horizontal covering of the region, we performed several horizontal tracks between Iasi and Roman at different altitudes following the main traffic axes: the European road on the north of the cities, and a circular exploration around the cities. We also performed tracks in remote atmosphere above the forest in order to evaluate the pollution gradient between urban and rural/remote atmospheres. We located the geographic coordinates of the vertical soundings according to the wind direction and the geographical position of the industrial zones.

*Figure 1* describes our flight plan:
- the ATR-42 takes off from Iasi airport
- we do a square around Iasi at constant altitude
- we go on a vertical profile downwind of Iasi
- we begin the first track towards Roman at high altitude FL180
- at mid-distance between Iasi and Roman, we do a vertical profile above the forest
- we reach Roman at low altitude
- we do a square around Roman at constant altitude
- we perform a vertical profile above Roman
- we follow the European Road at low altitude
- we reach back Iasi
3. MODIFICATION OF THE INITIAL FLIGHT PLAN

The initial flight plan was respected most of the time. A little time lack obliged us to shorten one of the vertical soundings. Considering urban exploration as a priority for this flight, we decided to shorten the second vertical sounding above the forest.

Moreover, we were supposed to fly on Sunday morning. We decided to postpone it until Monday afternoon preferring a working day in industrial areas and more intense car traffic.

![Fig. 2 Horizontal projection of the achieved flight](image)

4. FLIGHT PLANNING AND PERFORMANCES

This flight enabled to understand the importance of planning the trajectory accurately. The aircraft cannot fly under altitude of 500 feet, and the vertical speed can hardly be more than 500 feet/minute. Moreover, autonomy and reachable altitude for the aircraft depends on the payload’s weight and instruments mounted
on its surface which limits the aero dynamism. Besides, we noted that the flight strategy should be adapted and may be modified according to meteorological conditions. The track we decided to do following the European road to track the traffic pollution hardly led us to extract reliable observations and results. We assume that such a question requires more accurate flight strategy.

5. FAILURES OF SOME INSTRUMENTS

We mainly focused on the chemistry rack on the ATR-42 equipped with:
- an ozone monitor THERMO-ELECTRON 49PS
- a CO analyzer THERMO-ELECTRON 48CS
- a NOx monitor THERMO-ELECTRON 42C

The O₃ and CO instrumentations provided apparently quality results, but because of the correction which needs to be done on the CO measurements (correction for the baseline, removing the zero level calibration times), this data cannot be easily monitored during the flight. However, we encountered signal problems with the NOx monitor. In fact, the instrument was not calibrated before the flight. On figure 3 one can see the signal provided was only noise above 1200 m. We noticed some variation signal downwind Roman, maybe due to high NOx concentrations in the dynamic range of the instrument.

\[\text{Fig. 3 NOx concentration profiles above Roman}
- \text{Le profil de la concentration au-dessus Roman}\]
6. PRELIMINARY IMPRESSION ABOUT THE DATA

The collected data enabled us to establish the O$_3$ and CO concentrations above the region. We could clearly distinguish the boundary layer with the potential temperature and the humidity, and the clear discontinuity in the CO and O$_3$ concentrations. On the plot in figure 4, we can see four crossings of the PBL-Free troposphere limit. At about 3800s the artifact is due to onboard tests of the sampling line.

Fig. 4. - Overview of the two hours of the chemistry flight
L’aperçu des deux heures du vol de la chimie

Fig. 5. Potential temperature and absolute humidity profiles above Iasi during the flight
Les profils de la temperature potentielle et l’umidité absolue au-dessus de Iasi pendant le vol
From figure 5, the planetary boundary layer can be clearly distinguished from the free troposphere with the potential temperature and absolute humidity. It appears to be established around 2200 m. One can observe a zone of turbulence just under this altitude. The measured trace gases profiles confirm this altitude for the PBL (Fig 7 and 8).

The horizontal exploration above Iasi performed at a constant altitude of 2500 feet, showed concentrations ranging from 55 to 70 ppb. This distribution follows a horizontal gradient from the North West till the South East of the city. This was expected because of the wind direction (North West). The ozone is more intense downwind the city.

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Fig. 6 Ozone horizontal exploration at 2500 feet above IASI (concentrations in ppb)
- Exploitation de l’ozone horizontal à 2500 pieds au-dessus Iasi (des concentrations in psb)

Fig. 7 Ozone and CO profiles for the 3 soundings above Iasi, forest area and Roman
- Les profils de l’ozone et CO pour les trois l’analyse au-dessus Iasi, la forêt et Roman
On figure 7, we can observe a good homogeneity in the ozone distribution in the PBL in the region going from Iasi to Roman. This is due to the good convection occurring with sunny weather and low wind speed. In Iasi, the CO concentrations are higher than the concentrations encountered in Roman. This may be caused by the higher emissions sources from Iasi and its industrial zones. Around an altitude of 3200m, we observe an opposite variation from IASI and the forest for both species, which we do not explain.

We went to investigate more accurately O₃ distribution by plotting O₃ concentrations according to altitude in figure 8. O₃ concentrations are homogeneous in the PBL from 1000 to 2000m. Above the PBL many layers are identified and O₃ concentration varies in these layers. Between 3000 and 3300m a residual layer is suspected. Above 3300m the ozone concentrations get higher. These O₃ intrusions may be due to long range transport.

Back trajectories have been generated by NOAA HYSLIT Model to investigate this possibility (figure 9). Trajectories were generated for the past 120 hours at different altitudes. They show that air masses are reaching Iasi from the north and coming from Western Europe passing by Ukraine. To confirm these suppositions, we should investigate O₃ profile on the previous days.

Fig. 8 Ozone distribution above IASI
- Le partage de l’ozone au-dessus Iasi
Fig. 9 HYSPLIT back trajectories
Les trajets derrière HYSPLIT

Fig. 10 CO vs. O₃ concentrations above Iasi
Les concentrations CO vs. O₃ au dessus Iasi
From figure 10 we try to see a relationship between O₃ and CO concentrations. On the plot, we can distinguish two clusters of points distributed in the red and green circles. The points in the green circles present relatively constant values for both species (around 150 ppb for CO and 70 ppb for O₃). In comparison with figure 5, we can relate these values to the PBL. In the red circle, we can see more spread distribution of the concentrations. A correlation between CO and O₃ seems to be present. These values are linked to the concentrations above the PBL; the decrease of both species at 3200m is another clue for this correlation. CO available at these altitudes can be also due to long range transport. Having the NO₂ profile would be interesting. Indeed, because O₃ is produced with the photolysis of NO₂, we should see a different ratio between O₃ and NO₂ above the PBL if the ozone is not produced locally, due to the short life time of NO₂.

7. Conclusion

The flight “as0729”, dedicated for pollution tracking above Iasi – Roman, led to interesting observations concerning O₃ and CO distributions over these 2 cities, especially because photochemistry is enhanced during solar hours. O₃ and CO concentrations appear higher downwind the cities which is in accordance to what we expected. More observations, in particular at higher altitudes, let us think of O₃ intrusions due to long range transport. A correlation seems also to exist between the two species above the PBL. A more complete look out on the data of the flights of the days before is necessary to confirm these assumptions. The lack in NOₓ data is a potential handicap that restrains the possibility of evaluation of photochemical pollution.

8. Bibliography

http://www.arl.noaa.gov/ready/hysplit4.html
http://www.atmos.anl.gov/ABLE/
http://www.eufar.net
http://www.met.tamu.edu/class/metr452/models/2001/PBLproject.html